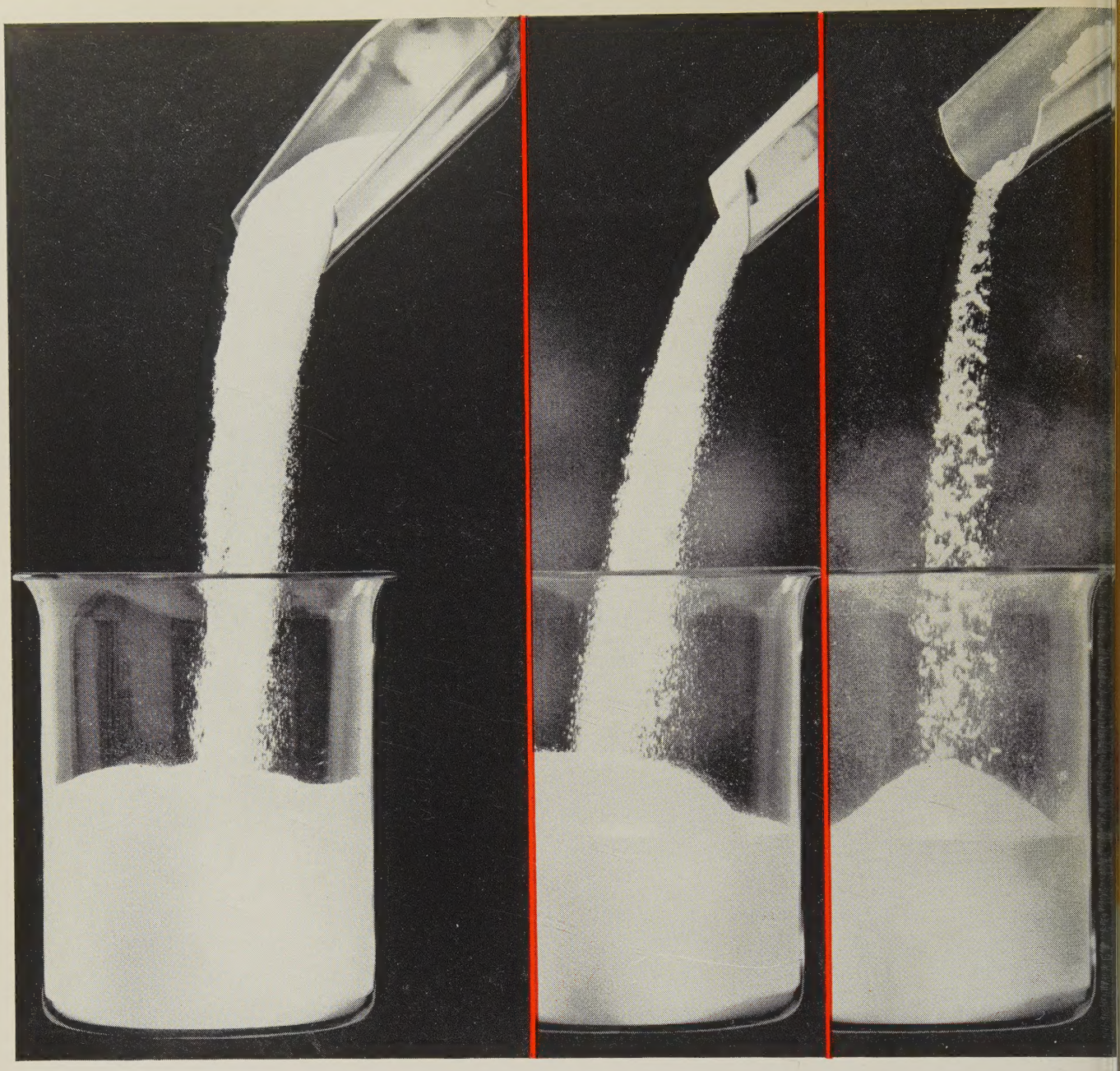
Tappi

PUBLISHED BY THE TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY

DECEMBER 1959

VOLUME 42 • NUMBER 12



this simple test demonstrates

Westvaco® Soda Ash

flows more freely... dusts less!

Pour a scoopful of Westvaco Soda Ash into a container (as we've done, left) Do the same with other ash (center and right)!

Note how quickly Westvaco Soda Ash pours, without raising clouds of dust . . . demonstrating that it will be faster and cleaner to unload and handle in your plant. That's because Westvaco Soda Ash is composed of unique, needle-like crystals that literally *roll* out of the scoop or hopper car. They don't grind themselves down to dusty fines.

Bigger surface area makes them faster to dissolve, too, and their chemical purity produces crystal-clear solutions. Westvaco Soda Ash is extremely low in iron, salts, heavy metals and insolubles . . . and entirely ammonia free.

We'd like to suggest a trial order. It's the best way you can demonstrate *all* the advantages of Westvaco Soda Ash in your process.

Putting Ideas to Work

fmc
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FOOD MACHINERY AND CHEMICAL CORPORATION

Westvaco Chlor-Alkali Division

General Sales Offices:
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UNVARNISHED TRUTH—Alpha® Protein improves brilliance of process colors

It takes a brighter, whiter, smoother, more uniform paper to snap out contrasting color in crisp detail without resorting to a varnish coat. The same is true when using the new gloss inks.

These fine paper qualities result when Alpha Protein is used as the coating adhesive. More than that, it lowers production costs.

Coating mill operators report that the extra solids possible with Alpha Protein give production increases up to 15%. More solids result in faster drying, faster machine speeds, higher coat weights.

Chemurgy paper specialists are always ready to serve you. Write or call for detailed information.

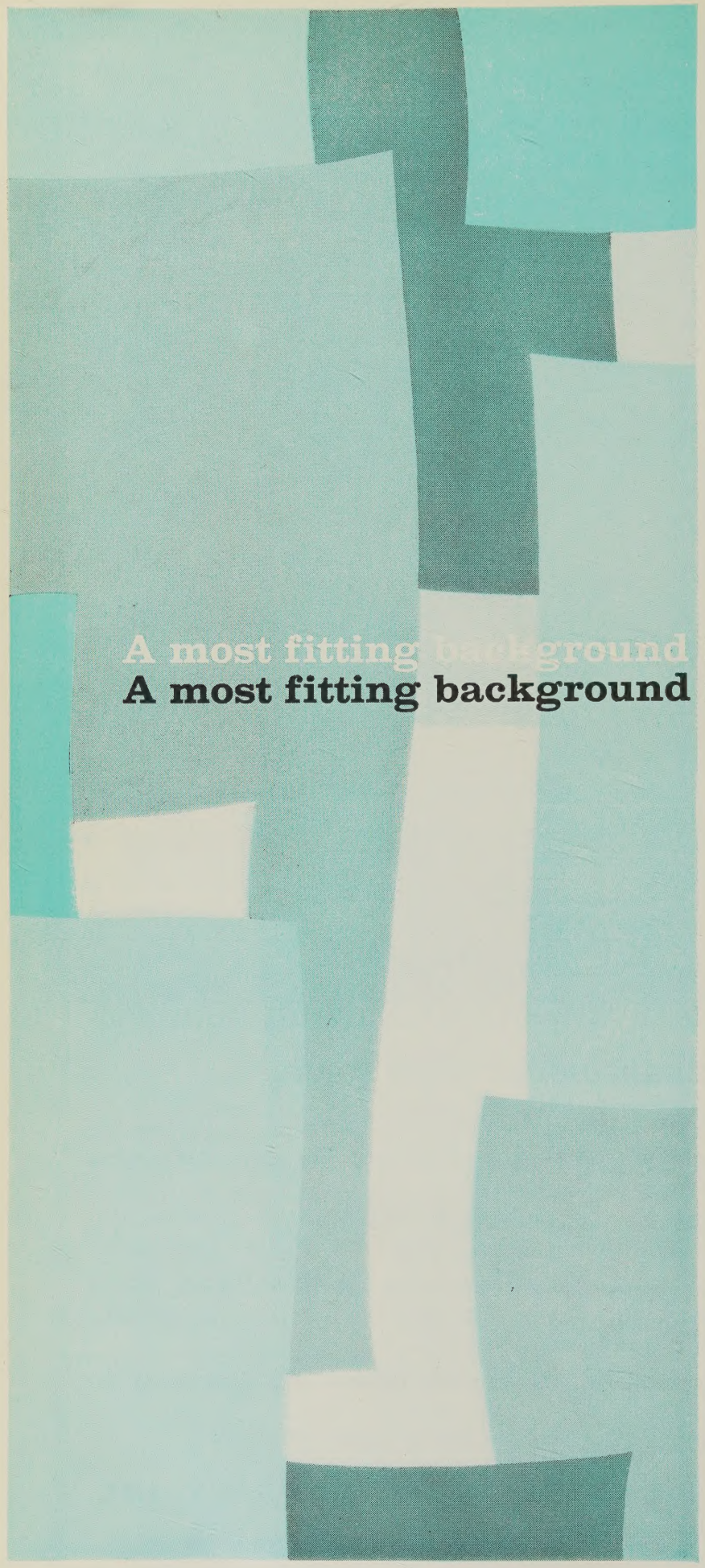
25

YEARS OF CHEMURGY EXPERIENCE

CENTRAL SOYA COMPANY, INC.
CHEMURGY DIVISION

1825 N. Laramie Avenue · Chicago 39, Illinois

This is a sample of 4-color process lithography on Alpha Protein-processed paper



A most fitting background for type

A most fitting background for type

Dyestuffs by Geigy.

Here's a new approach to Blue and Green bond and printing papers.

Solophenyl® Blue 8GL

A low cost direct blue with the necessary fastness properties for fine papers.

Paper Bond Blue BP

A low cost Alizarine type blue with rapid developing characteristics and needed properties for high grade printing papers.

Use the above two blues as a base for blue shades or in conjunction with

Chinoline Yellow P Conc
Diphenyl Fast Yellow 4 GP

for green shades.

Our technical staff will be glad to demonstrate the adaptability of those products.

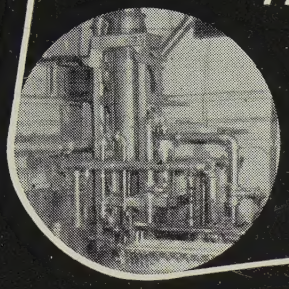
Geigy Dyestuffs

Division of Geigy Chemical Corporation
Saw Mill River Road, Ardsley, New York

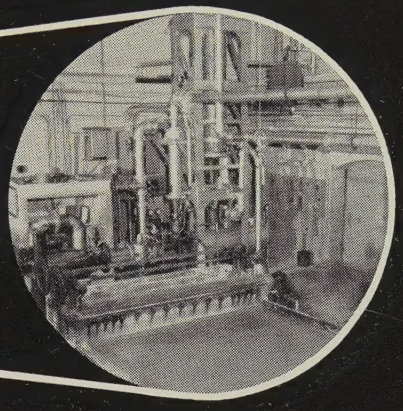
Branch Offices: Charlotte • Chattanooga • Chicago • Los Angeles • Newton Upper Falls • Philadelphia • Portland • In Great Britian: The Geigy Co., Ltd., Manchester

"We're making our finest Glassine— At the fastest we've ever run our machines" . .

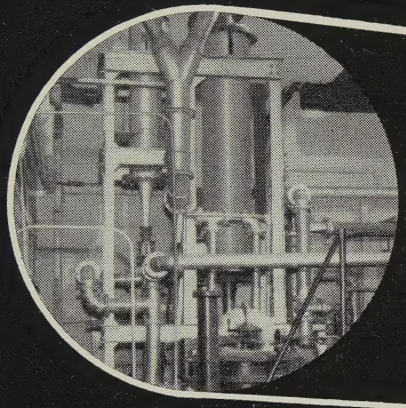
The Nicolet Vorvac Story



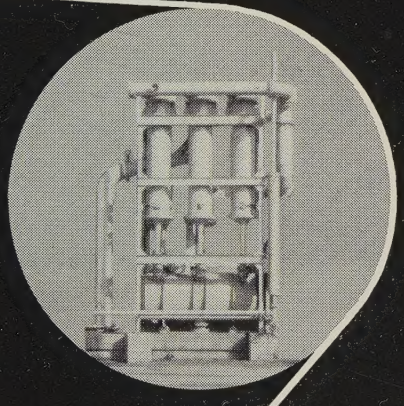
JUNE, 1955, MACHINE NO. 1
Initial Vorvac system started up.



JAN., 1956, MACHINE NO. 2
Vorvac system started up.



JULY, 1958, MACHINE NO. 1
Added a 6-16 Vorvac system and new Head Box, allowing 50% increased water capacity.



DEC., 1958, MACHINE NO. 3
Ordered Vorvac system for this new machine. Will be similar layout to illustration at left.

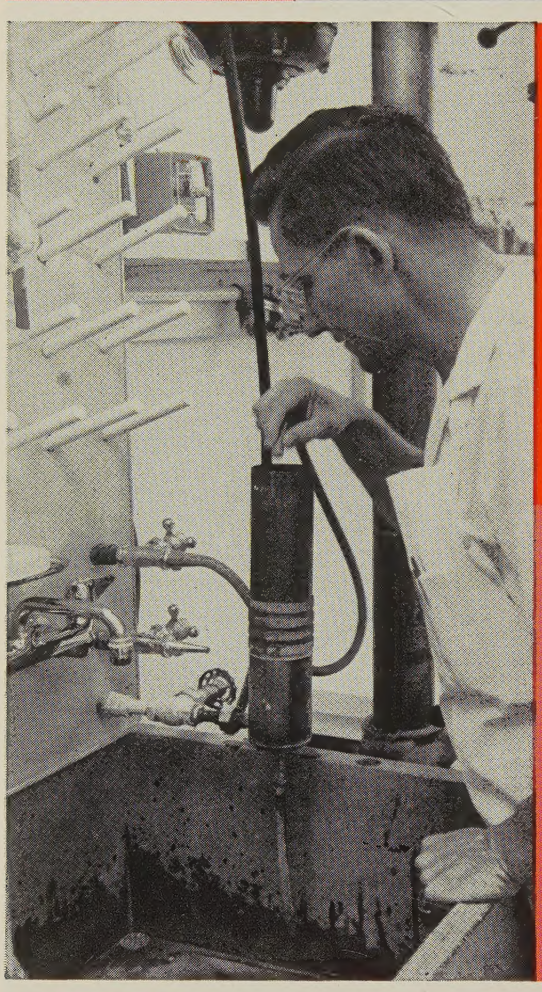
Investigate the advantages of a Vorvac system, the time spent will save dollars in production costs.

NICHOLS FREEMAN
VORVAC
SEPARATOR

Nichols Engineering & Research Corp.
70 Pine St., New York 5, N. Y.
405 Montgomery St., San Francisco 4, Calif.
1477 Sherbrooke St. W., Montreal 25, Canada

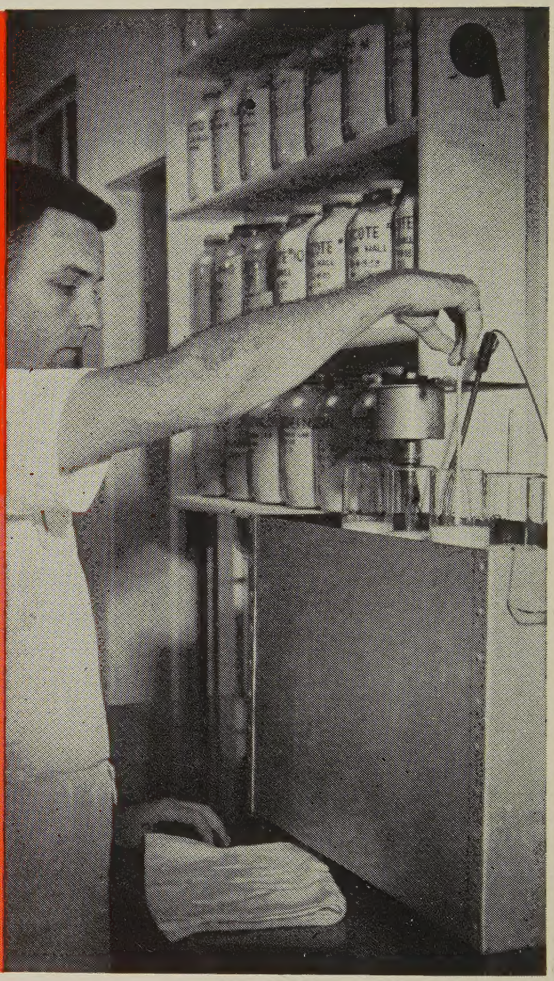
Huber Lab Report:

THESE TWO HUBER TESTS ARE HIGHLY IMPORTANT TO YOUR PAPERS



COMPREHENSIVE STUDY of oversized particles *(left)* using a nest of several screens: namely, 80, 170 and 325 mesh. (TAPPI Standard Procedure T645m)

PARTICLE SIZE TESTS, using a hydrometer method *(right)*, determine particle distribution to about one micron. Analysis of finer particles is made with special centrifuges.



Many important innovations for the paper industry have come from the Huber Clay Laboratories. Among these are the VISCONTROL process for assuring uniform viscosity in clay and the new line of Hydrafine Clays.

The comprehensive quality control tests of our Huber, Ga., laboratory are well-known throughout the paper industry...and our labs maintain a close relationship with customers by rendering technical service. We can duplicate all of the essential stages of paper making from sheet making to finished filled or coated paper. We will be glad to discuss with you how *our* lab services can improve *your* product.

J.M.HUBER CORPORATION 630 THIRD AVENUE, NEW YORK 17

Mines & Plants: Huber, Ga.; Graniteville & Langley, S.C.

HUBER

DECEMBER 1959

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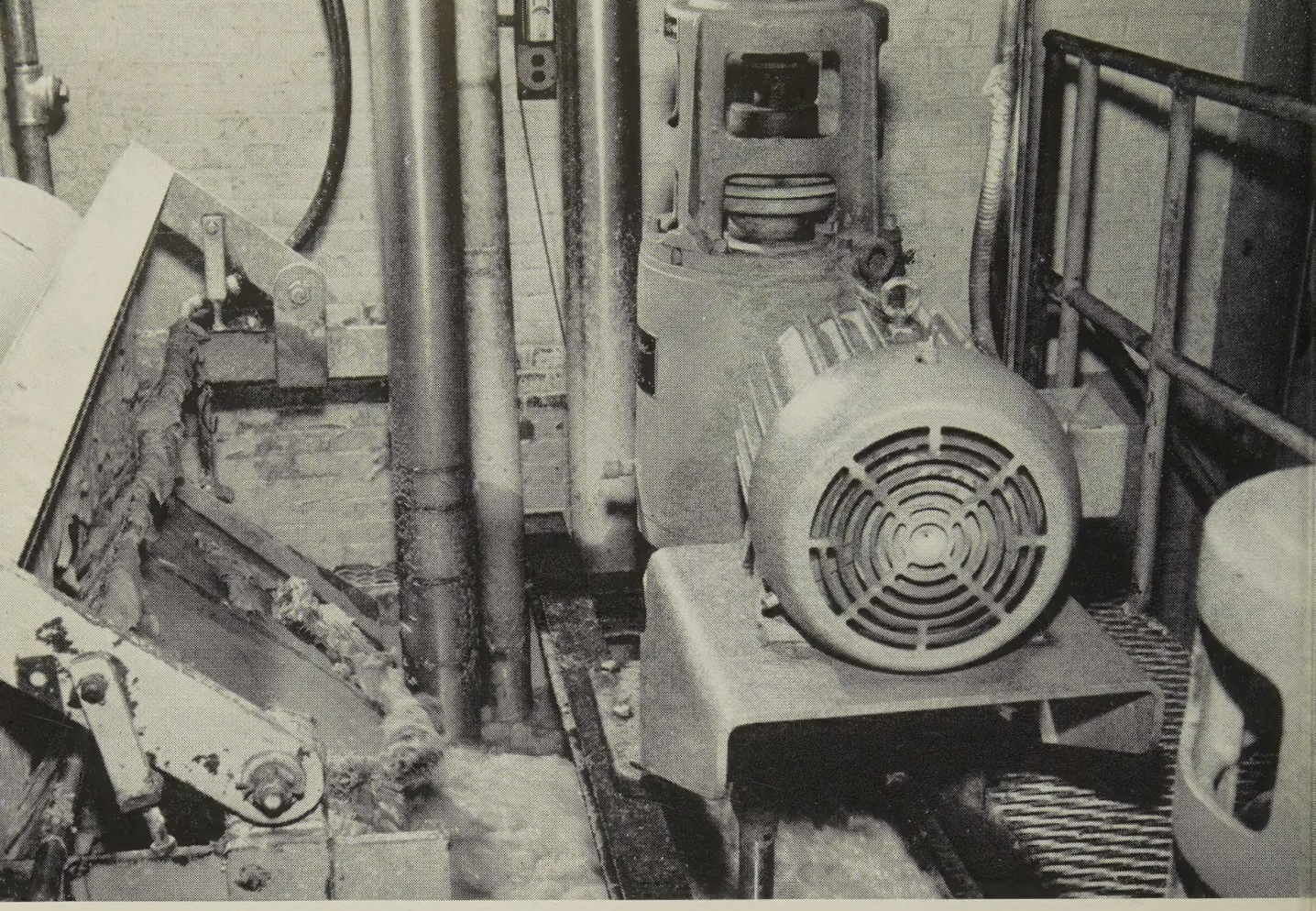


Controlled turbulence created by LIGHTNIN Stock Agitator rapidly separates stock fibers at Gould Paper Co., Lyons Falls, N. Y.

How to make stock uniformity toe the mark

This repulping system gives the mill a tight rein on stock consistency and pH.

Here you see step one. Hardwood stock at a soggy 12% consistency drops from the washers into both ends of a 32-foot-long dilution chest. The tiled chest is 4 feet wide and carries a 4-foot stock level.

Incoming stock meets a stream of acid water recycled from the secondary washer. In each 6-foot-long end section of the chest, the turbine on a 15-hp LIGHTNIN Stock Agitator drives stock and water in a powerful mixing flow.

With this kind of agitation, fiber length and freeness are essentially unchanged. Controlled turbulence does the work of separating the fibers.

Consistency anywhere in this part of the chest stays within 0.1% (bone dry) of the average. Retention time is four minutes.

Rapid pH control Next, uniform stock tumbles over a weir into the 20-foot-long center zone of the chest. Here two more LIGHTNIN Agitators rapidly disperse strong sulfuric acid to bring pH to 2.5 and hold it there as stock discharges to the secondary washer. Uniform consistency and acidity are provided at all conditions up to the design maximum of 4.0% (b.d.).

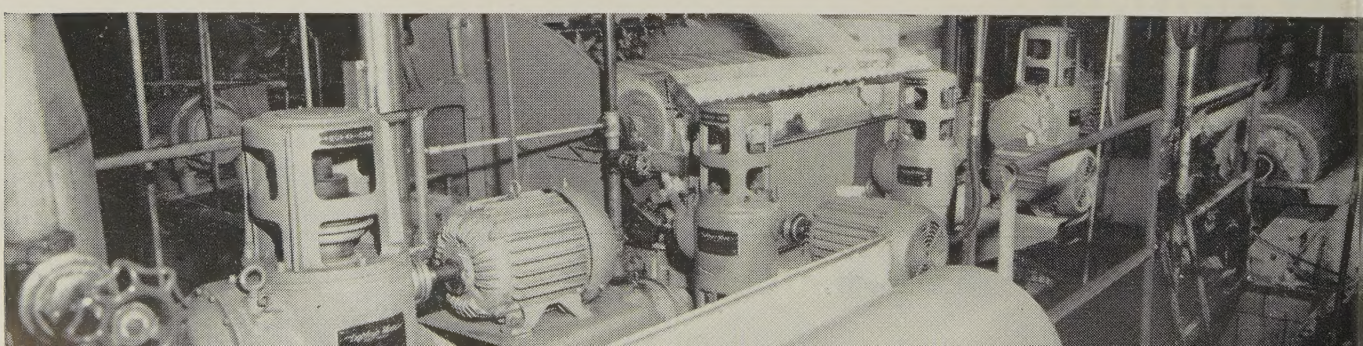
This MIXCO-designed system was delivered to the mill just five weeks after the day it was ordered. It is only one example of the precision control you can bring into your pulping and paper-making operations with LIGHTNIN Agitators in your chests.

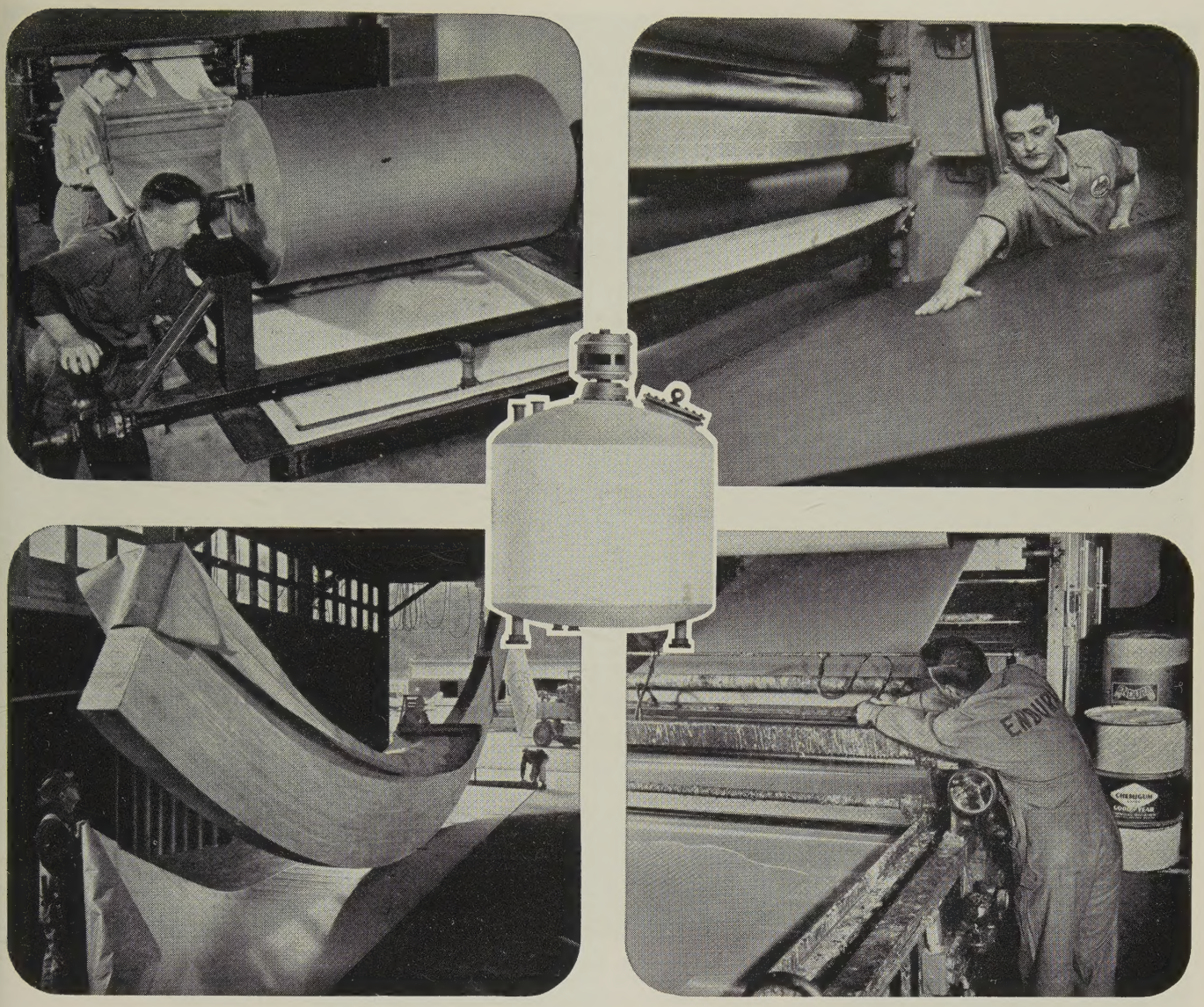
To find out more about this kind of mixing and the guaranteed results it gives you, call in your LIGHTNIN representative now. His name is in Thomas' Register and in the yellow pages of your phone directory. Or write us.

MIXING EQUIPMENT Co., Inc., 142-n Mt. Read Blvd., Rochester 3, N.Y.
In Canada: Greey Mixing Equipment, Ltd., 100 Miranda Ave., Toronto 19, Ont.

Lightnin® Mixers
MIXCO fluid mixing specialists

Dilution chest has repulp sections at ends, pH-control section in center. Installation adapts easily to changes in mill requirements.





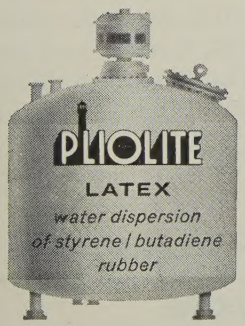
For quality papers—four quality latices!

Major improvements in paper are rolling out of the paper industry at a constantly increasing rate. Papers with *special* qualities are being developed for *special* needs. As this trend continues, manufacturers are becoming more and more selective about latices. Quality is vital. And the latex chosen must be *exactly right* for the specific type of paper being made.

To meet this need, Goodyear offers four basic latices: PLIOLITE *Latex* in two forms (as a rubber or resin dispersion), PLIOVIC *Latex* (dispersion of vinyl copolymer resin) and CHEMIGUM *Latex* (dispersion of nitrile rubber). All are available in a broad range of monomer ratios, particle sizes and types of stabilization. They can be used alone—or in combination with each other—or as modifiers of your present materials.

Among the benefits you can expect from these latices are: better body, drape, strength and dimensional stability—improved flexibility and softness—exceptional resistance to aging—and outstanding wear qualities.

You can also expect the finest in technical assistance when you work with a Goodyear latex. Contact your Goodyear Chemical Division Representative for all the facts. Or write for details—including latest *Tech Book Bulletins*—to Goodyear, Chemical Division, Dept. L-9432, Akron 16, Ohio.



GOODYEAR
CHEMICAL DIVISION

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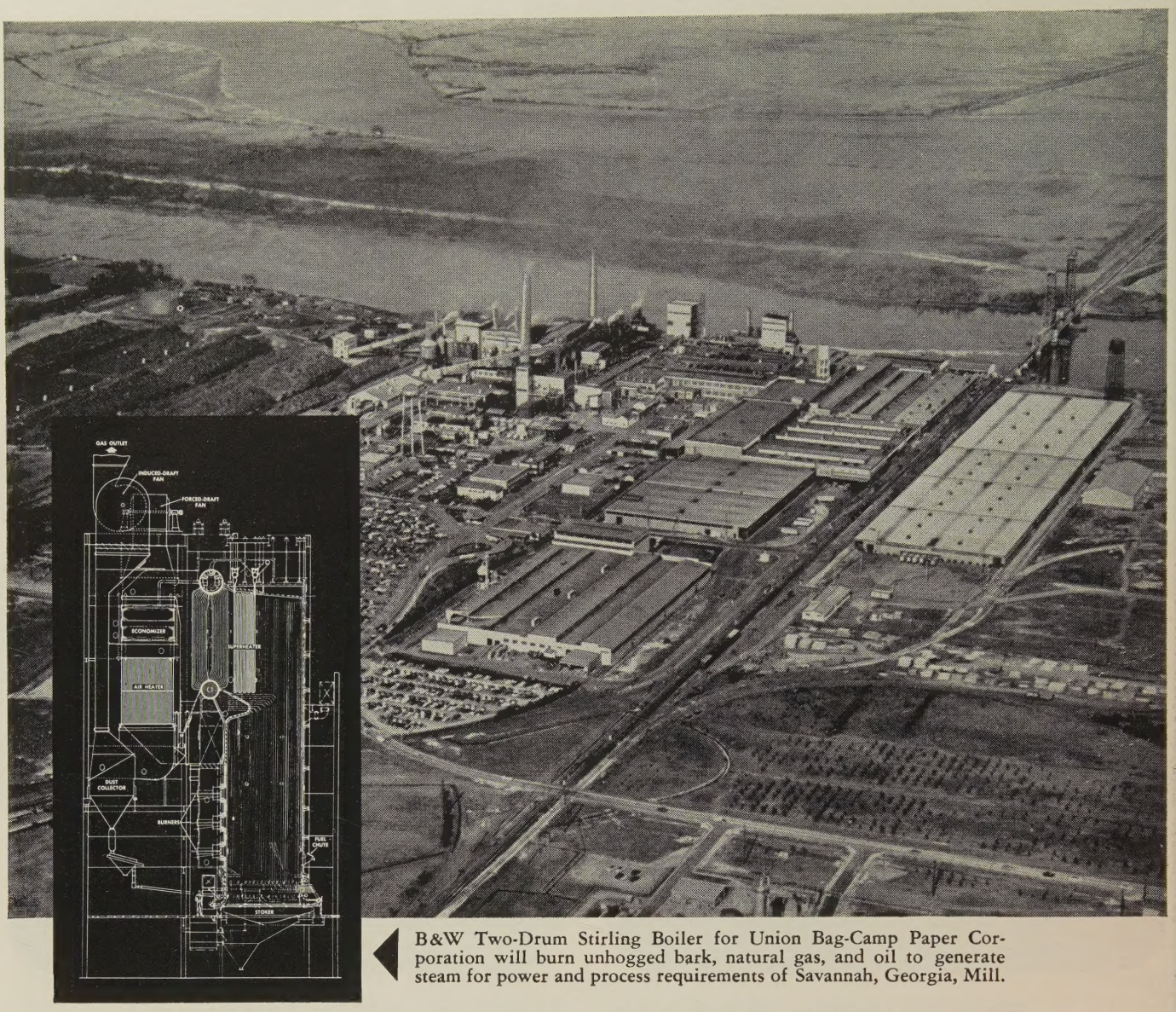


B&W Two-Drum Stirling Boiler for Union Bag-Camp Paper Corporation will burn unhogged bark, natural gas, and oil to generate steam for power and process requirements of Savannah, Georgia, Mill.

Why America's Largest Bark-Burning Boiler is a B&W Boiler

The highest rated bark-burning boiler ever built will soon be generating 550,000 pounds of steam per hour at Union Bag-Camp Paper Corporation's huge mill at Savannah, Georgia. It will burn unhogged bark as a primary fuel but can also be fired with natural gas or oil—singly or in combination with the other fuels. The unit has a design pressure of 1250 psi at the superheater outlet and will operate at 950 F.

The designer and manufacturer? Babcock & Wilcox. Long associated with burning all kinds of fuel for steam generation, B&W has proved time and again its ability to supply dependable and efficient boilers of every size to burn every conceivable kind of fuel. And B&W's manufacturing capacity and know-how assure quick and dependable delivery schedules. That's why profit-minded steam users everywhere choose B&W to solve their fuel burning and steam generating problems.

If you're looking for ways to increase boiler efficiency and achieve fuel economies that will increase your profits, your first step is a talk with B&W. Contact your local B&W sales engineer or write The Babcock & Wilcox Company, Boiler Division, Barberton, Ohio.

B&W

THE BABCOCK & WILCOX COMPANY

BOILER DIVISION

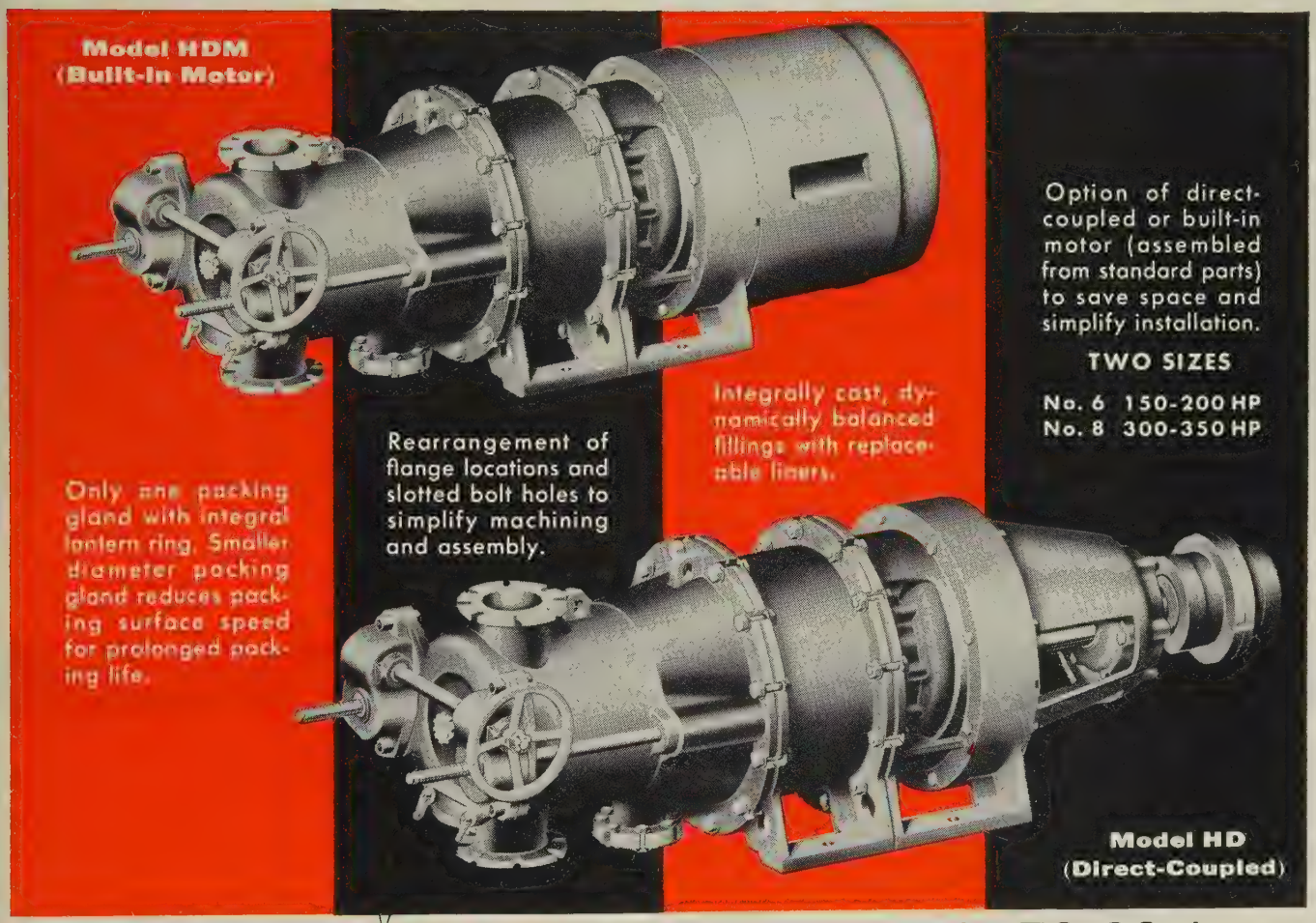
P-822

The NEW MORDEN

Morden's creative engineering, combined with the cooperative experience of nearly 300 paper mills using more than 1000 Morden refiners, brings you a completely new form . . . of the "Stock-Maker" and "Stuff-Maker."

These new machines are engineered to:

1. Further improve the "Stock-Maker's" reverse-flow, sealed-pressure beating treatment—so well proven through the last 25 years.
2. Retain the "Stuff-Maker's" straight-through-flow jordaning treatment—requiring only a simple filling interchange to give brushing or cutting treatment—now all in the same refiner housing.
3. Maintain Morden's high quality of materials, workmanship and performance—with savings of 20% in initial equipment and replacement filling costs.


Model HDM
(Built-In Motor)
Option of direct-coupled or built-in motor (assembled from standard parts) to save space and simplify installation.
TWO SIZES
No. 6 150-200 HP
No. 8 300-350 HP
Integrally cast, dynamically balanced fillings with replaceable liners.
Rearrangement of flange locations and slotted bolt holes to simplify machining and assembly.
Only one packing gland with integral lantern ring. Smaller diameter packing gland reduces packing surface speed for prolonged packing life.
Model HD
(Direct-Coupled)

INVESTIGATE NOW FOR SAVINGS UP TO 20%!

Ask for further description of the new "Stock-Maker" and "Stuff-Maker" and how they can benefit your operation. We shall be happy to visit you for an in-the-mill discussion of your requirements.

MORDEN
MACHINES COMPANY

3420 S.W. Macadam Avenue • Portland 1, Oregon

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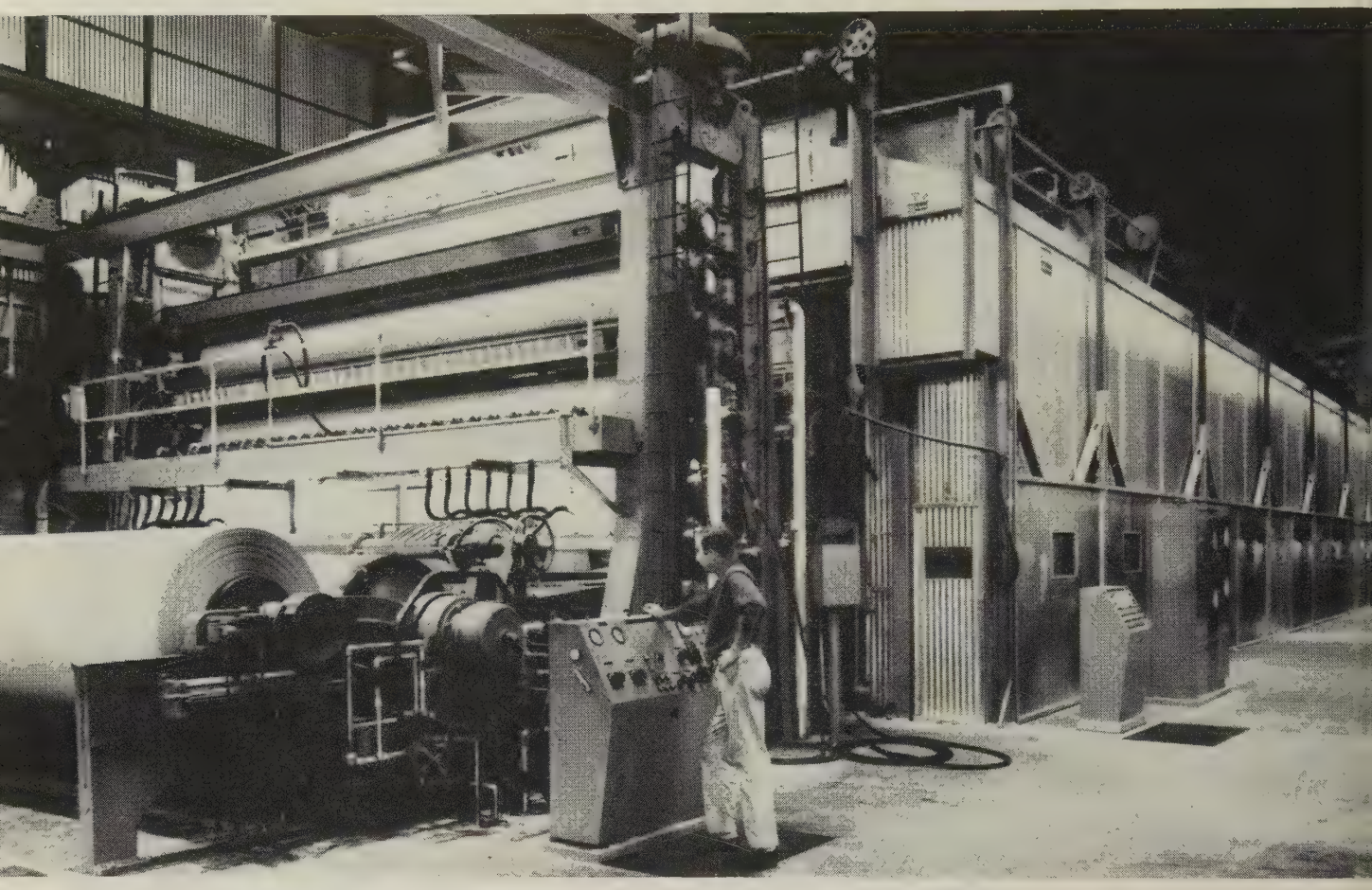
SYSTEM ENGINEERED PRODUCTS VALUE IN USE.

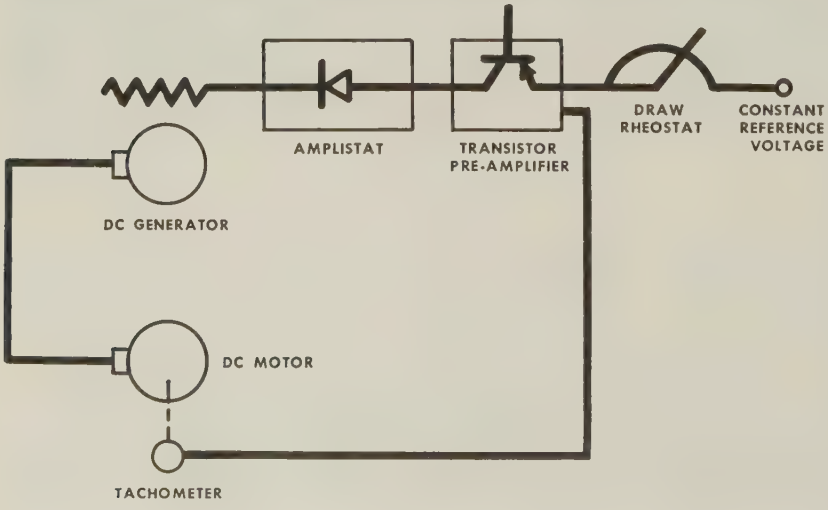
Southland Paper



DESIGNED FOR NEWSPRINT PRODUCTION AT 2500 FPM, Southland's new No. 4 paper machine was built by Pusey and Jones Corporation, powered by a General Electric multiple-generator sectional drive. The new machine, 270 inches in width, uses 14 G-E drive motors totalling more than 3000 horsepower.

GENERAL ELECTRIC DRIVES ARE SYSTEM ENGINEERED

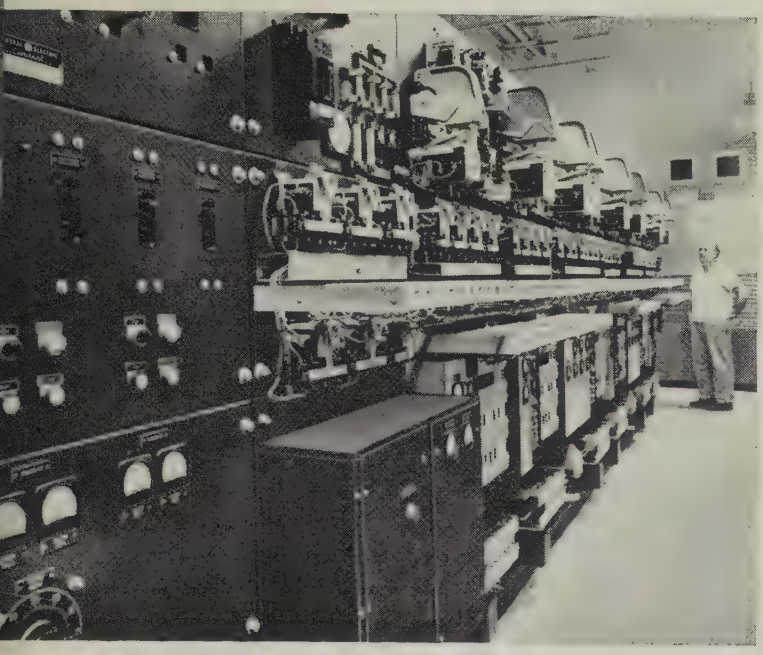
HOW THE G-E MULTIPLE GENERATOR SYSTEM WORKS



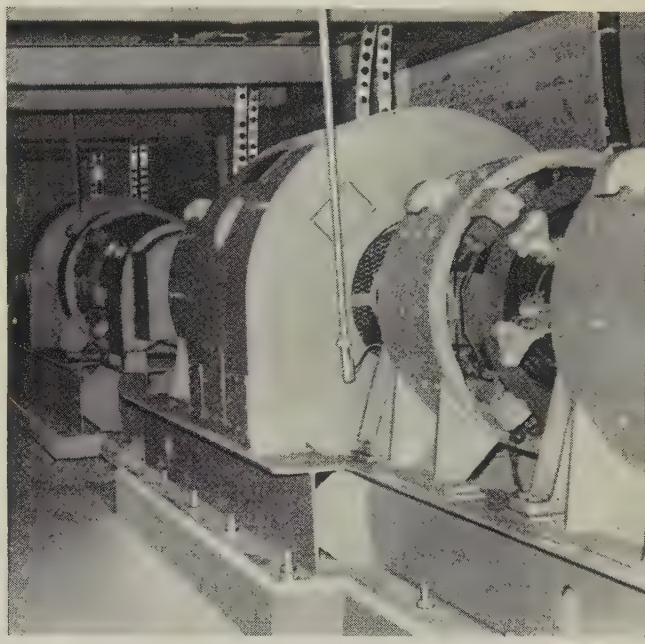
Each section motor operates on generator voltage control. The motor speed is measured by a tachometer, whose output voltage is compared with the over-all machine's constant reference voltage. With even the slightest difference between the two voltages, the transistorized preamplifier responds instantly through an amplistat regulator to change the generator voltage, maintaining the exact desired motor speed.

specified General Electric Drive featuring new transistor amplistat

HERE'S WHY . . . • Improves machine availability
• Maximum machine flexibility
• Reduces electrical maintenance



G-E STATIC SPEED REGULATOR provides high accuracy, fast response control. Amplistat power amplifier and completely sealed transistor pre-amplifier give long-life, trouble-free operation and reduce costly unscheduled downtime.



DEPENDABLE POWER is supplied by two G-E MG sets, each driven by a 1500-hp synchronous motor. Separate generator for each section adds flexibility and simplifies maintenance.

FOR ALL PAPER MAKING APPLICATIONS

Southland Paper Mills' new No. 4 paper machine at their Lufkin, Texas mill, powered by a General Electric multiple-generator sectional drive, presents a major advance in drive systems for the paper industry.

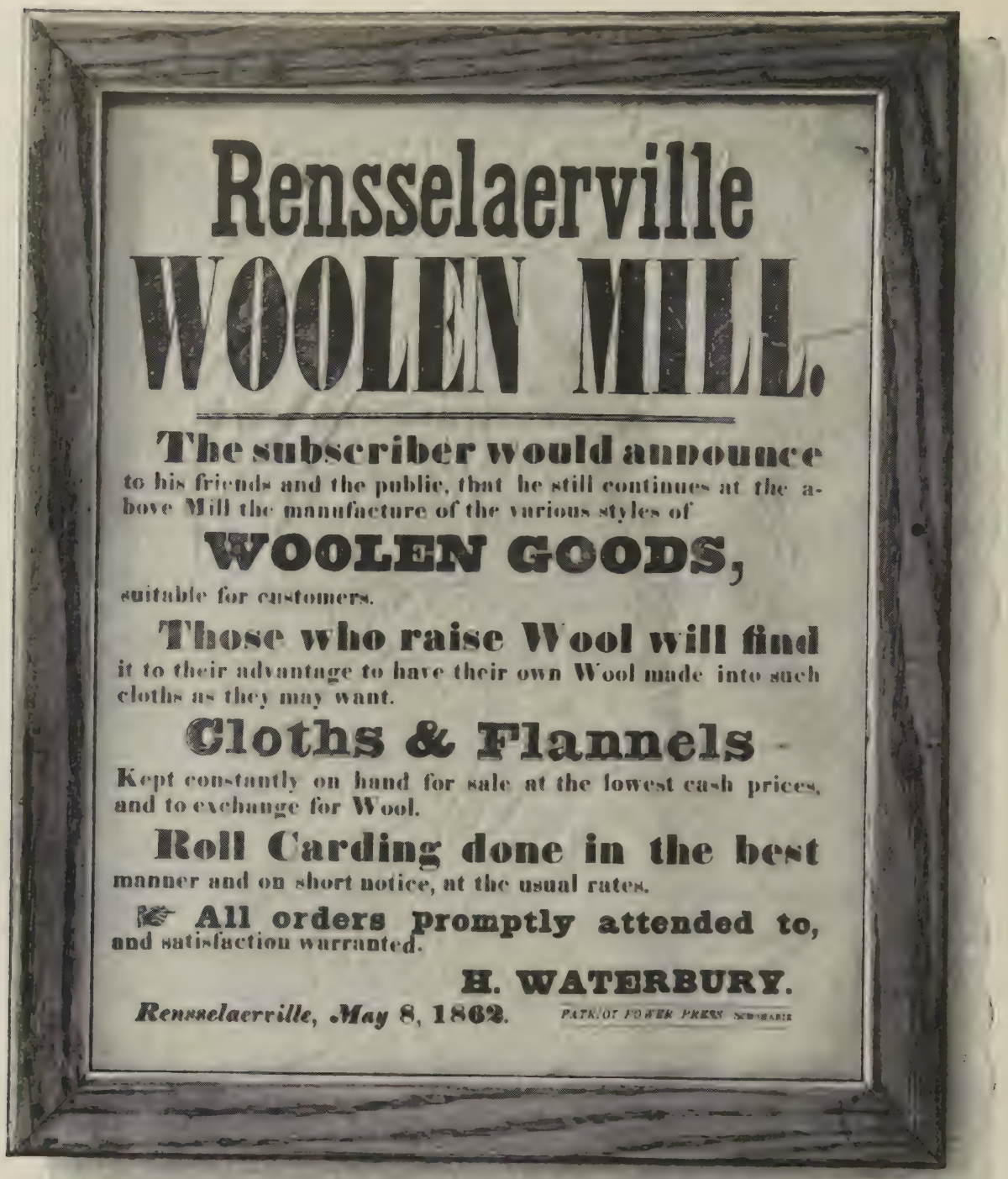
New technology, such as use of transistors and magnetic amplifiers in the G-E static speed control, provides trouble-free, reliable operation to increase machine availability and reduce maintenance time and expense. Result: *greater output.*

Co-ordination of the equipment into a flexible, easy-to-expand electrical system resulted from close co-operation between Southland engineers and General Electric application and service engineers.

General Electric engineering services also can help you design, equip and install a well-integrated electrical system suited to your specific needs. For more information on paper-mill drives, call your nearest General Electric Apparatus Sales Office or write to General Electric Co., Section 655–23A, Schenectady 5, N. Y.

Progress Is Our Most Important Product

GENERAL ELECTRIC


Rensselaerville
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The subscriber would announce
to his friends and the public, that he still continues at the above Mill the manufacture of the various styles of
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suitable for customers.
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it to their advantage to have their own Wool made into such cloths as they may want.
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Kept constantly on hand for sale at the lowest cash prices, and to exchange for Wool.
Roll Carding done in the best
manner and on short notice, at the usual rates.
All orders promptly attended to,
and satisfaction warranted.
H. WATERBURY.
Rensselaerville, May 8, 1862.
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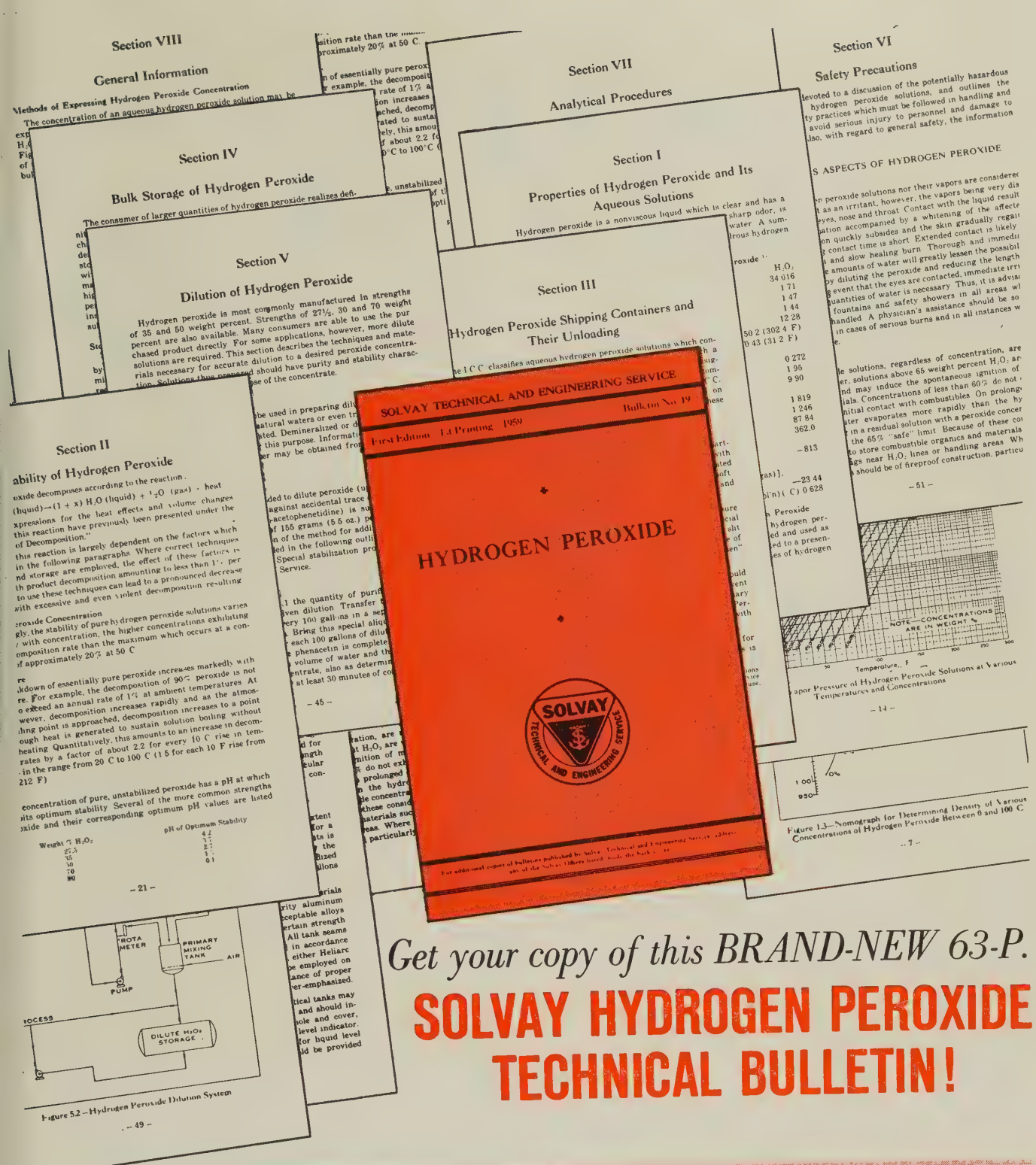

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The Present and Future Status of Waxed Paper

M. B. KANE

I HAVE been asked to discuss the status of waxed paper as of now and as of the year 1965 from the semi-marketing, semitechnical, and competitive viewpoints, Choosing me for this was fortunate because I probably know as little about the subject as anyone. Nevertheless, I hope that some of the things I say will stimulate a few of you to take steps toward more effective use of the qualities waxed paper can supply so cheaply.

First let us consider the volume of business. I would suggest that any of you interested in this read "Petrowax Makers Face Tough Competition" appearing in the Aug. 8, 1959, issue of *Chemical Week*. After reading this article, I made the following estimates on the usage of petroleum waxes. Paperboard will use 800 million pounds of wax in 1959 and will use 1 billion pounds in 1965—an increase of 20%. Waxed paper will use 250 million pounds of wax in 1959 and 250 million pounds in 1965—no change. Other uses of wax will amount to 250 million pounds in 1959 and 300 million pounds in 1965—an increase of 20%. Assuming no inflation, this means that paperboard will use from 60 to 70 million dollars worth of wax in 1959 and use around 80 million dollars worth in 1965. During this same period waxed paper converters will spend about a constant 20 million dollars a year for wax.

These figures lead to the conclusion that waxed paper will not continue to hold its present share of the market if we look at it on a percentage basis. This, of course, must happen if plastics and foils are used to an increasing degree in fields now supplied by waxed paper unless waxed paper enters new fields. Since waxed paper has been used for so many years for so many things, it is very difficult to find new fields for it, and any increase in its usage will probably require some improvement in the quality-cost ratio of waxed paper, or more convincing evidence that its present quality-cost ratio is better than the consumer realizes. I want to emphasize the term quality-cost ratio because this is waxed paper's strongest point.

Next, let us consider wax paper from the semitechnical viewpoint. Since the majority of waxed paper is used for packaging food I will confine my discussion to this use.

Waxed paper is conposed of two components, paper and wax, which have several things in common. Among these are:

1. Low cost per square foot of useful surface. In other words, wax and paper are low cost materials.
2. They occur in nature in combination with other materials from which they must be separated before being used for producing waxed paper.
3. No chemical synthesis is used in their preparation. (The chemical compounding has been done for us.)
4. If they are not used for waxed paper, each can be economically utilized for other purposes by its producer. (The wax producer and paper manufacturer do not depend entirely on wax paper for their operation.)
5. Each can be processed to accent certain properties if other properties are sacrificed. As a result, they usually represent compromises between several desirable properties.

Looking at these five points, some of the strong points and weak points can be surmised. In evaluating these points it should always be kept in mind that quality in the business world has to be stated as quality *per* something, and it should always be *per* the right something. For example, it is meaningless to say a certain metal is the strongest metal. Instead we say it has the highest tensile strength per square inch or per pound per foot or per dollar per foot, etc.

In the past 15 years wax blends have contributed much to waxed paper and the compromise principle has been used to great advantage, but maybe we should now look more closely at other approaches. If we consider point 1, the low cost of waxed paper per square foot, and point 5, the ability to accentuate certain properties, we see that there is a possibility of obtaining high qualities at low costs. For example, suppose we make a low cost wax that has a very high resistance to water vapor penetration but with poor gloss, poor seal, poor blocking, etc. Suppose we make a second low cost wax which has very good gloss retention, good resistance to scuff, and good resistance to blocking but with poor seal and poor resistance to water vapor penetration. Finally, suppose we make a third low cost wax with very good sealing strength but not much else. If these are combined in a sheet by some method whereby they are kept physically separate in the form of layers or pockets so each can perform its function separately without degradation by the other components, we might have a seven-course dinner instead of hash at the price of hash. Laminated sheets are examples of this thinking, and applying the sealing wax at a packaging machine in the same way glue is applied is another example. It might be well to remember in building such a sheet that there are no rules against using things other than wax and paper in the combination.

The fact that paper and wax occur in nature and only require separation from other components (point 2) with no chemical syntheses involved (point 3) is probably of no particular value. Nevertheless, the chemical compounding has been done for us and it may be easier for us to lower separation costs than it would be to lower chemical syntheses costs if we were to make a product to replace waxed paper.

If a product is to increase or even retain its market,

M. B. KANE, Technical Director, The KVP Co., Kalamazoo, Mich.

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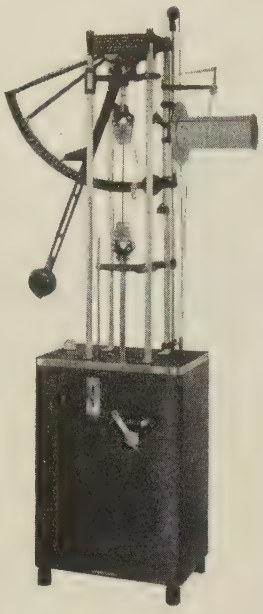

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it needs a strong driving force from somewhere. It might come from the raw material supplier, it might come from the fabricator, or it might come from the consumer. Point 5 raises the question that waxed paper may be in the position of not having a strong enough driving force because very few of the people concerned with it would be too greatly affected if it gradually disappeared from the market. Production of waxes represents a very small portion of the petroleum industry's operation and the disappearance of waxed paper would not be a major catastrophe for them; most converters who wax paper would not find it too difficult to change their operations to products other than waxed paper if its use were discontinued; and the consumer of waxed paper can find other materials nowadays to replace waxed paper if necessary.

If the continuance of waxed paper is not a life and death situation to anyone, why are we interested in it? I think the answer is that it can perform certain functions more cheaply than any other material. In addition, it has some operational properties that make it attractive to the converter and the consumer. Waxed paper is easy to fabricate and it performs well on the packaging machine.

The important properties of waxed paper are usually thought of as being its resistance to penetration by water as a liquid or vapor, the ease with which it heat seals, and the glossy nature of its surface.

RESISTANCE TO WATER PENETRATION

The permeability of one material through another material is greatly affected by the ratio of crystalline regions to amorphous regions, and the wax producers have done some good work in applying this principle to waxes as a means of improving their resistance to water vapor transmission. Maybe more work would result in a wax that would be far superior to anything else for moisture protection per dollar per square foot.

SEALING

There are many ways of joining two surfaces but the most common method is to do it by applying a liquid between the surfaces and then causing the liquid to solidify. The liquid may be:

1. A solution which solidifies by evaporation.
2. A dispersion which solidifies by evaporation.
3. A melted solid which is caused to freeze.
4. A liquid which polymerizes to a solid.

Of these, the melted solid which freezes has many advantages. It can be melted and frozen very quickly; its fluidity can be easily controlled by temperature, making it possible to use it as a lubricant in the operation. There are other advantages and, of course, disadvantages. Wax is a good heat sealing material because it melts at low temperatures to a very fluid material and is easily and quickly solidified. Another advantage is that the stiffness and dimensions of the sheet are not changed during the sealing operation.

GLOSS

Since petroleum waxes are transparent they follow Fresnel's law and have the same gloss properties as other transparent materials. While it is possible to obtain as good a gloss with wax as with other transparent materials, some waxes have the ability to retain this gloss better than other waxes. If gloss retention under adverse aging, temperature and scuffing conditions were the only properties required in a wax it could well be possible to develop a superior wax for gloss.

I have taken up enough of your time but would like to say a few words in conclusion. Waxed paper can continue to be an increasingly valuable commodity if its quality-cost ratio is improved. Since the continuance of waxed paper does not appear to be indispensable to the survival of any one particular industry, the combined efforts of the petroleum industry, the paper manufacturer, the waxed paper fabricator, the consumer, and the package machine manufacturer will probably be needed if it is to retain its share of the market. The next 5 or 10 years will tell how interested we are in continuing the production and use of waxed paper.

Presented at the Fourteenth Plastics-Paper Conference of the Technical Association of the Pulp and Paper Industry, Chicago, Ill., Sept. 20–23, 1959.

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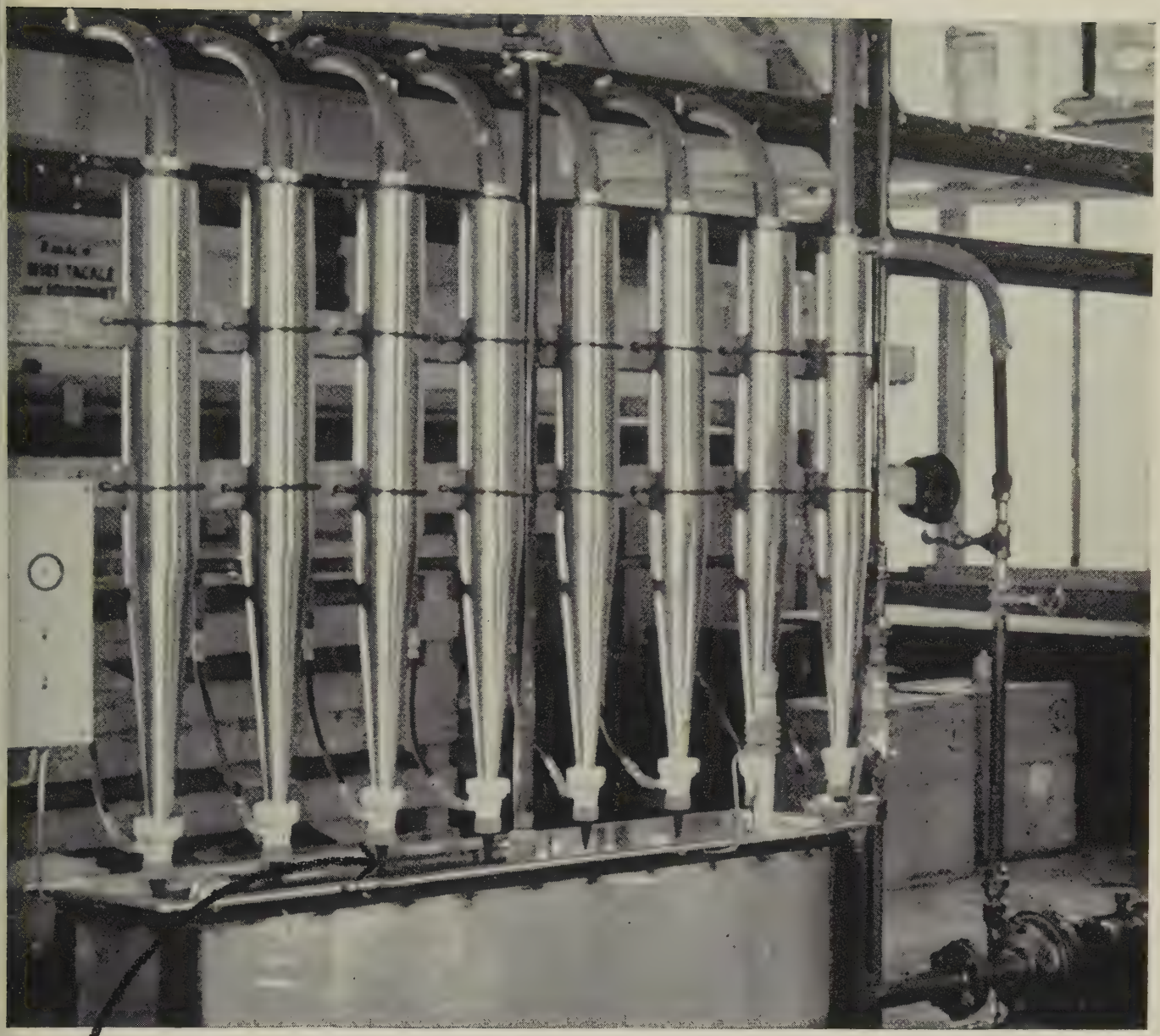

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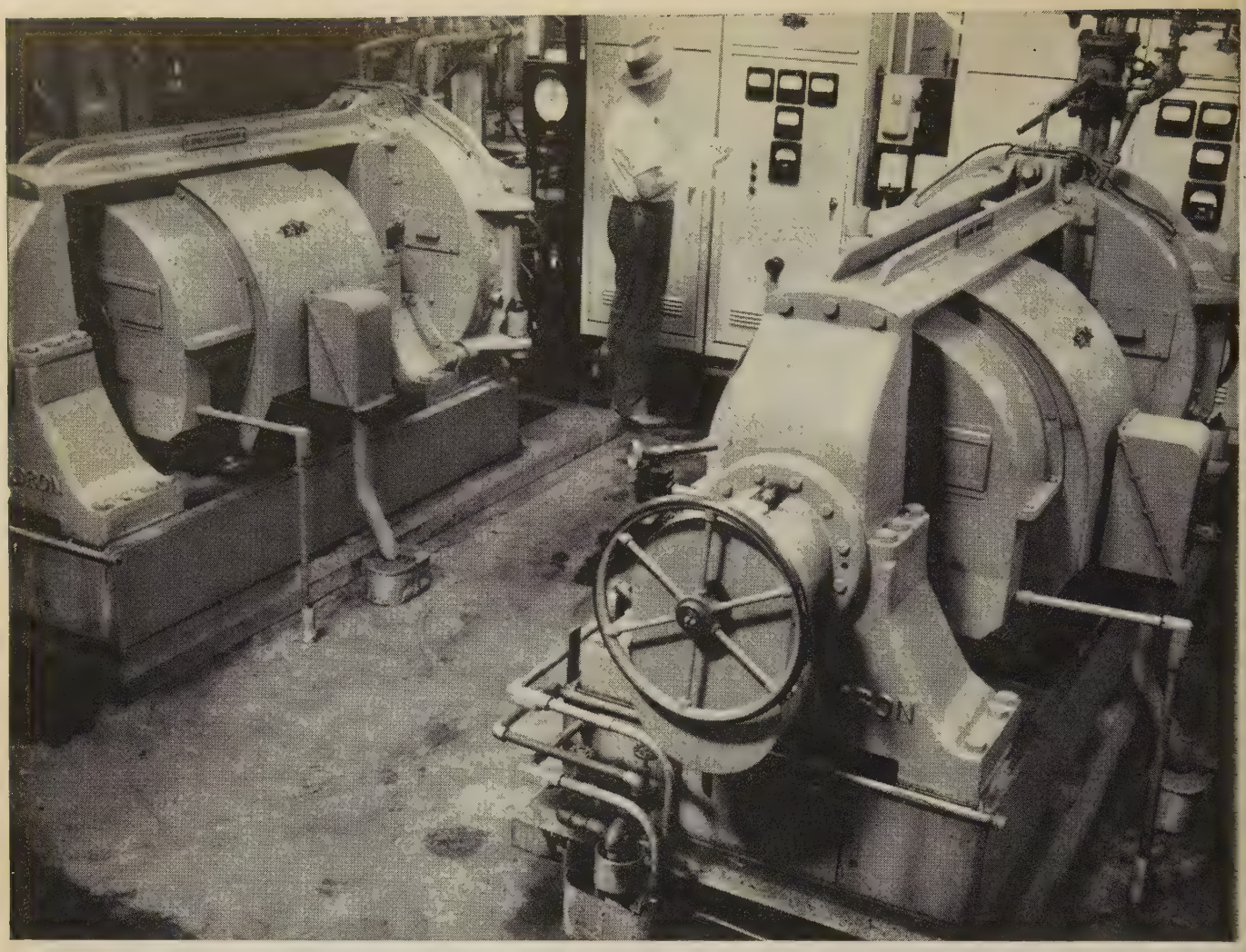

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Many natural polymers that contain labile hydrogen atoms react with acrylonitrile under suitable conditions to give cyanoethyl derivatives. In general, aqueous caustic has been used to catalyze these reactions. Since the extent of cyanoethylation of the polymer can be varied by suitable choice of reaction conditions, a variety of products may be obtained from one starting material. Under certain conditions, cyanoethylation is accompanied by hydrolysis; in these cases, many of the nitrile groups are hydrolyzed to carboxylic acid salts, thereby producing a polyelectrolyte.

When acrylamide is used, carbamylethyl derivatives are produced; this process is known as carbamylethylation. Essentially, the reaction conditions are the same as those described for cyanoethylation.

As might be expected, the physical properties of polymers change when such modifications are effected. Cyanoethylation causes hydrophilic polymers to become more hydrophobic and when carried to a high degree, may confer solubility in organic solvents. Carbamylethylation has the opposite effect in that water sensitivity is increased. Cellulose can, indeed, be made water soluble.

The special properties imparted through modification of wood pulp with acrylonitrile make papers that are more useful for many specific applications. Among the "plus properties" which characterize paper made from cyanoethylated pulp are (1) resistance to thermal degradation both mechanically and electrically in a sealed system (2) dimensional stability, and (3) resistance to putrefaction.

Of particular interest to those who have investigated the prior art in this field may be Cyanamid's "dry method" of cyanoethylation, which has no visible liquid phase. Modification of pulp and other natural products by this new method can be accomplished with minimal quantities of acrylonitrile and caustic.

References describing methods of cyanoethylation of various natural polymers as well as properties and suggested applications of the end-products are given in the following outline:

CELLULOSE:

COTTON —Compton, et al., *Textile Research J.* **25**, 58–75 (1955)

Grubber & Bikales, *Textile Research J.* **26**, 67 (1956)

JUTE, MANILA, SISAL } American Cyanamid unpublished data

GUMS:

Moe, U.S. Patent 2,461,502 (1959)
Moe, U.S. Patent 2,520,161 (1950)

STARCH:

Houk & Bock, Canadian Patent 434,619 (1946)
Sample, U.S. Patents 2,836,511 & 512; 2,837,

LIGNIN:

Walker, U.S. Patent 2,816,100 (1957)

PROTEINS:

CASEIN —Cowan, et al., U.S. Patent 2,594,293 (1952)
McKinney, et al., U.S. Patent 2,775,565 (195

SOYBEAN—Cowan, et al., U.S. Patent 2,594,293 (1952)

WOOL —Bikales, et al., *Textile Research J.* **27**, 80 (195

For additional information on the modification of natural polymers with acrylonitrile and acrylamide, contact Cyanamid's Petrochemicals Department.

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Saturated Papers—Technical and Marketing Aspects

R. H. MOSHER

THE field of saturated papers is a broad one and might be defined as including cellulose sheet materials which have been treated, impregnated, or saturated with another substance. In the broad definition this would include paper containing large percentages of waxes, oils, soluble cellulose derivatives and glues, as well as the natural and synthetic resins and rubbers. In common practice the definition is somewhat narrower and for the purpose of this discussion I will limit my comments to paper treated with synthetic resins and rubber materials to the degree that the sheet properties are measurably modified. (The treatment for wet strength is, of course, specifically excluded from this product area.) Some of the earliest saturated papers of this type were the natural rubber and glue-glycerin saturated simulated leather materials used in the gasket and artificial leather fields in the early 1930's. Phenolic resin treated materials correspondingly have a long and continuous history of use in the field of structural and electrical panels. From these early products have developed a variety of synthetic resin and rubber containing materials which are beginning to find use in today's industrial economy.

The major turning point for the industry was in the late 1940's when the wide range of synthetic resins and rubbers which were developed before and during World War II became available to the paper converting industry in production quantities. Another major factor contributing to the growth of saturated materials, particularly at the paper manufacturers level, was the development of synthetic resins and rubbers in latex form. The handling of a water-dispersed system is a natural thing for the papermaker and, thus, made possible the saturation of paper with these compounds at the mill level. Prior to this time most of the saturated materials other than those made using natural rubber latex were produced in converting operations which were physically separated from the paper mills.

At the present time the various types of saturated products fall into two major classifications: (1) those containing thermosetting resinous materials, and (2) those containing thermoplastic resins or rubber materials.

The first area, which includes those products containing thermosetting resins, is mainly involved with phenolic or modified phenolic resin treated sheets as I am limiting consideration here to products which are manufactured for external sale as industrial raw materials. On the other hand, there are large quantities of melamine resin treated paper produced as well as quantities of polyester resin treated stock; however, other than in the few specific instances, these materials are saturated as required at the plant of the utilizing organization due to their relatively short process life. Most of the phenolic resin treated products, on the other hand, are more stable and are true industrial raw materials in that they are produced by one company and supplied to a customer who converts and fabricates them according to the desired end use. Such products include the phenolic resin impregnated papers which are supplied to the plywood industry as a plastic surfacing medium, and to the plastic laminating industry as core stock and backing sheets. Other phenolic resin treated papers are used in the manufacture of filters for oil and gasoline as well as for air and chemical fluids. Some of the major applications at present of plastic surfaced plywood are reusable concrete forms, highway signs, siding and decking, shelving, furniture, and both decorative and functional structural panels. The filter field has only recently begun to show growth owing to the interest of some of the automotive and aircraft companies in new concepts of filtering oils, gasolines, hydraulic fluids and the air going into automobile carburetors utilizing specially designed and disposable saturated paper filter media.

The second major field, or that covering the thermoplastic resin and rubber saturated papers, involves a wider variety of product applications. Such papers are manufactured today from a variety of pulps and are available containing a range of saturants depending upon the properties desired in the treated sheet. Most of the large resin and rubber companies have available their own formulations in both latex or solvent dispersed form and although the most common base materials are the Buna-S and Buna-N synthetic rubbers, the vinyls, polystyrene and acrylic resins and neoprene rubber are also beginning to find limited usage. They are available either as complete saturating formulations from the manufacturers, or the proper latices or base resins can be purchased and formulated according to the specific requirements of the individual saturator. Some of the applications of these products are in the general area of textile replacements: i.e., backings for artifical leather and trim stock; bookbinding materials; wall, shelf, and counter coverings; and floor coverings.

Other applications are in the field of pressure sensitive tape backings, gasket stocks, separator papers, map and label stocks, and abrasive papers. It must be realized, however, that this is a specialty field and in many of the product areas, it is necessary to develop a new sheet design for each individual customer and application.

Most saturated materials are manufactured commercially by both papermakers and converters using a secondary saturating operation where the base paper is made on the paper machine and the resin or rubber incorporated in a secondary treating operation. On the other hand, certain of the specialty paper manufacturers alternately produce some saturated papers directly on the paper machine. This has been done by

R. H. MOSHER, Asst. Sales Manager, Technical Papers Division, Kimberly-Clark Corp., Neenah, Wis.

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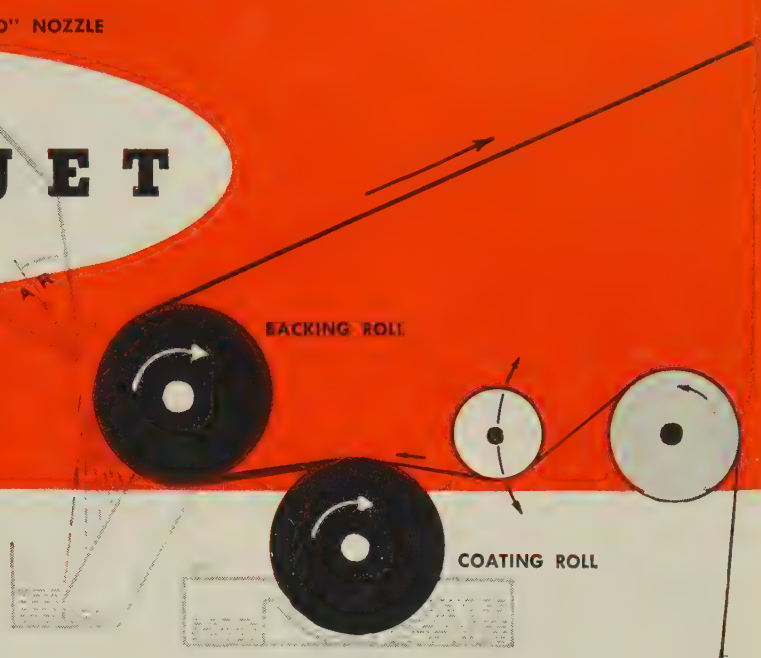

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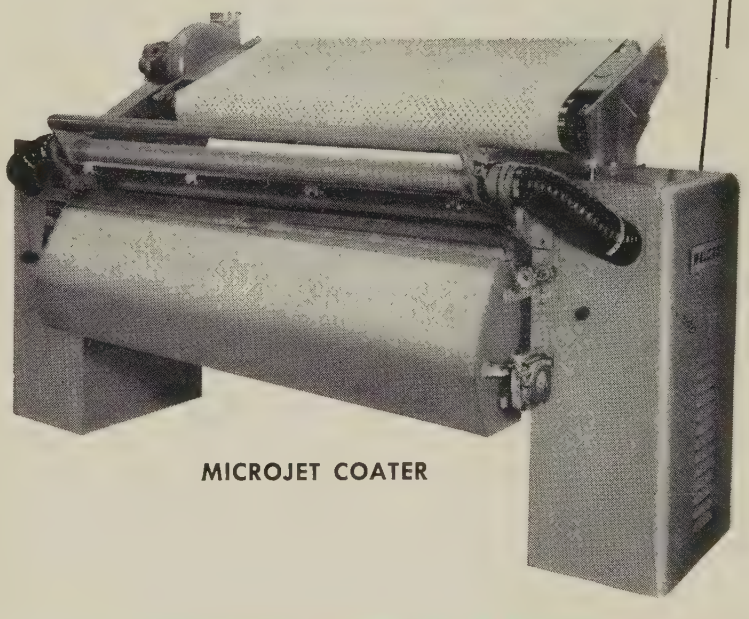

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incorporating the resin in latex form somewhere on the wet end of the paper machine, i.e., beater, stock chest, or headbox. One specific technique used to incorporate the resin in the formed sheet, but before any drying operations, is identified as the Novak wet web saturating process. Alternate methods of resin incorporation on the machine may take place after the sheet has been formed and mechanically pressed but not dried. In the third phase the resin may be incorporated at the size press, coating section or calender stack after the sheet has been partially or completely dried according to standard papermaking technology. Each of these methods offers certain advantages and some corresponding disadvantages; however, one major requirement of any papermaking machine is volume. For this reason there are very few saturated product end users which offer sufficient volume to justify direct machine production. Where they are so manufactured they often utilize relatively slow and narrow equipment which is not profitable in the manufacture of standard grades. I am sure that all of you present here are aware that it is not possible to set up a paper manufacturing unit to produce a 5000 or even a 10,000-yd. order of a specialized product. Perhaps another good yardstick of the amounts of these materials produced is that they are usually sold by the yard rather than by the pound.

It is very difficult to set an exact measure of the growth in this portion of the industry as in many applications the saturated paper is completely embedded within the final end product and its presence known only to the manufacturer and the saturated paper supplier. It has even been suggested that the increase in the sales volume of the resin and rubber manufacturers to the paper and the converting industries might be a suitable growth indicator. On the other hand, the amounts of such materials which are used in coatings so dwarf those used as saturants that this has developed into a very poor yardstick. There just does not seem to be enough product or interest to justify any assembly of formal statistics on this area. There is no trade association.

On the other hand, gentlemen, there is no question but what this is a business which equally fascinates the technical man, the purchasing agent, and the sales or merchandising manager. The product possesses intriguing physical characteristics and represents a high unit dollar sale. On the other hand, there have been no indications that saturated papers are even beginning to approach commodity status with any of the end products involved. Even in the plastic surfaced plywood applications, the figures of the D.F.P.A. indicate that the annual production of these specialized grades represent less than $1^1/_2\%$ of total Douglas-fir plywood output and has been stabilized at the present level for several years. New applications as they appear generally represent extensive development programs between the supplier and his potential customer. The marketing operation is highly technical and usually time consuming in nature.

In summary, saturated papers represent an intriguing but relatively small business when compared to the parent paper industry. The marketing problems are those of an industrial raw material and in general these products are not sold through the traditional paper industry sales channels. It is a business which measures its sales in terms of yards rather than pounds or tons. The dollar unit of sale is high, but there are few items which even begin to approach commodity standards. Perhaps what I am suggesting is that, if I have roused your interest with this discussion, you recommend to your management that it carefully market-research any areas which you may wish to follow up before investing any capital monies, or basic research time. Even the well recognized areas of artificial leather and masking tape backing stocks which are among the largest consumers of saturated papers collectively use relatively few tons of product.

Presented at the Fourteenth Plastics-Paper Conference of the Technical Association of the Pulp and Paper Industry, Chicago, Ill., Sept. 20–23, 1959.

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The Present and Future of Polyethylene Film

GORDON HUNGERFORD

First of all, I should like to express my great pleasure in being here and being permitted to participate in these discussions. I have been aware of the work of the TAPPI organization for a number of years and have always been a great admirer of this organization. The sessions so far have been most interesting and instructive.

When I was asked by Mr. Sullivan to come here to discuss the present and future of plastic films, I was more than happy to do so, since this is a favorite subject of mine. Indeed, it is my constant preoccupation. However, I do not wish to represent myself as an expert in the matters that I am about to discuss. My acquaintance with the packaging industry began about four years ago when I joined the Kordite Corp., so that my knowledge is limited to the specific field of plastic films in packaging, and I am not particularly expert in the wax paper, gummed tape, saturated paper or other businesses. Therefore, you all may wish to take what I have to say with a grain of salt for at least two reasons: (1) I am somewhat perhaps overly enthusiastic about the future of plastic films in the packaging business, since this is my present bread and butter. (2) I have only limited knowledge of the areas in which you gentlemen are expert. However, I do have a reasonably good understanding of what is going on in the plastic film industry, and I shall be glad to share this limited knowledge with you.

First of all, it may be instructive to analyze why plastic films have become a factor at all in the packaging business. This is a new phenomenon in industry and may have occurred as somewhat of a surprise to people who have long been in the other packaging fields. The key to understanding this, of course, lies in a consideration of the properties of these new materials and their costs. I should like to recall to your mind some basic numbers which relate to the question of properties versus cost.

Most of these numbers have been published in recent months and years and I am sure you have all seen them. I have inserted a few additional items which have not normally been shown in the published lists.

There are several points worth noting. One is that 1-mil polyethylene film at present prices is about as cheap as 37-lb. waxed kraft paper. Another is that $^1/_2$-mil polyethylene film is about as cheap as 36-lb. kraft paper.

Now, admittedly, these films are not nearly as strong as paper nor are they as stiff. They are difficult to wrap around articles, are difficult to seal, and are difficult to fabricate into other articles such as bags. Characteristically they also easily develop electrostatic charges which compound all the problems of use. However, they do have some virtues. In the first place they are quite low in cost; roughly equal to paper. The other is that they are transparent. Present polyethylene films can be made to have the clarity and gloss of cellophane. (These new films which are a considerable improvement over conventional polyethylene films are just now reaching the market.) Another virtue is toughness and resistance to tear propagation. Still another is water resistance. These films are permanently unaffected by water and also are good moisture vapor barriers.

I believe it is doubtful that polyethylene films would find wide utility considering their somewhat disadvantageous properties were it not for the fact that they are so cheap. When one considers how polyethylene is made, it is difficult to foresee any cheaper high polymer. Certainly ethylene is one of the cheapest raw materials that exists and also the costs of converting ethylene into polyethylene are quite low. Unlike other high polymers which may cost 50 cents to 2 or 3 dollars a pound to make, polyethylene does not cost this much and, therefore, it is possible to sell resins at 35 cents per pound and to sell film for about 50 cents per pound.

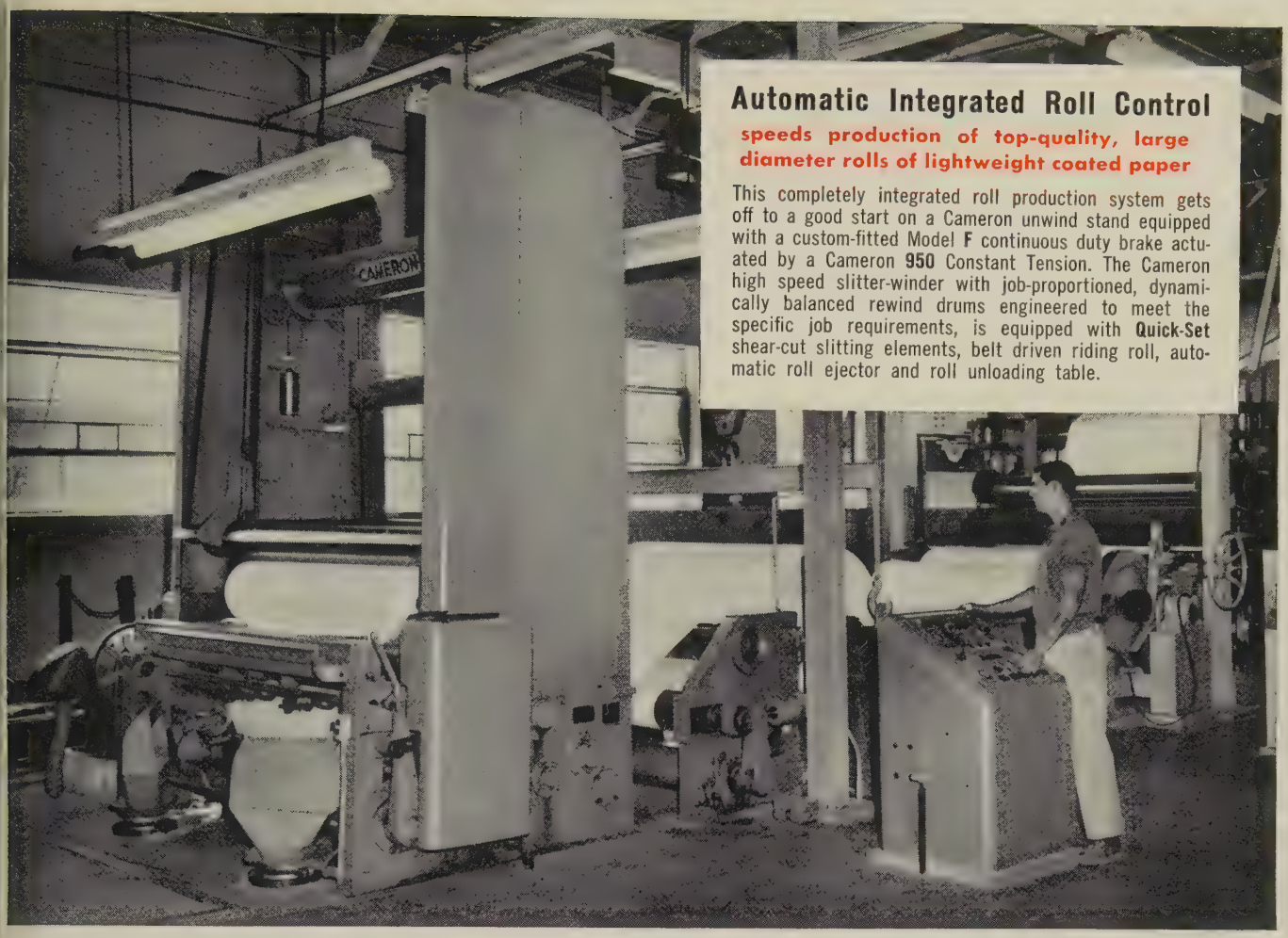
Now it is most difficult to predict in advance for any given application whether the pluses of a product will outweigh the minuses or vice versa. Some judgments can be made, but the market place, of course, is the final arbiter.

There are several cases with which we may be all familiar in which the market place has decided that polyethylene film is a better packaging material than paper.

One case with which I am familiar illustrates how the particular balance of properties of polyethylene film enabled it to supplant paper, even though the costs were not less. This is the case of the garment delivery bag with which all of you are familiar. Large bags made of $^1/_2$ mil polyethylene film finally became competitive with paper bags pricewise and became preferred by the consumer, interestingly enough, and not the dry cleaner, primarily because the housewife can see what is inside the bag. Parenthetically, that same housewife, whom we love so dearly, was so careless with her bags that we almost became condemned by the public as mass baby murderers virtually overnight.

Another case which has not fully developed yet is that of the bread wrapping market. As you undoubtedly know, there is a strong trend toward the use of polyethylene film for bread wrapping. My company is heavily involved in this program and we have been most gratified with the results. We assume that the reasons that polyethylene seems to be winning acceptance in the bread wrapping market are that the film is transparent like cellophane and the moisture retention in the package is considerably superior to that of wax paper. These properties, of course, would

GORDON HUNGERFORD, Vice-President, Research and Engineering, Kordite Corp., Macedon, N. Y.



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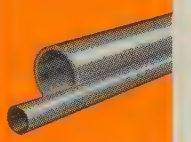

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not be enough if the film were substantially more expensive than wax paper, but fortunately for us the films are competitive pricewise with wax paper and cellophane. Therefore, even though it is more difficult for bakers to use these films even with the various collections of packaging machine conversions which have been developed, they are enjoying increasing use.

Now these are only two paper markets which are now being invaded by such films, largely on the basis of the low cost of the films and their peculiar balance of properties.

I think we all recognize that the plastic film industry is pretty much in its infancy. Certainly the prices of resins have not reached their low points as yet. Also, typically, the converter has not developed his technology nearly to the extent that the paper industry has and he has a long way to go in achieving a very high quality industrial operation. Further, until recently there has been very little technical research in the film-making part of the industry, but recently this has been considerably expanded and there are many complex technical developments under way which promise stronger and stiffer films at still lower cost. Therefore, as properties improve further and prices decline further, one might logically expect still deeper penetration of the paper markets by plastic films.

For example, one major company has publicly announced their intent to produce biaxially oriented polypropylene film. You may be interested in the properties of such a film as published by one supplier, namely Minnesota Mining and Manufacturing. Such films have enormous tensile strength and great stiffness, but low tear strength. They also have other highly undesirable properties which may limit their utility unless they are overcome. Also, the cost of these films is not yet known, but because their processing is quite complex, it is likely that they will be rather expensive on a per pound basis. Hence, they will have to be used at very low gages to be economical and, therefore, their properties on a per-inch-of-width basis may not be outstanding.

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Table I. United States Film Market

Year	*Total film in million pounds*
1950	15
1951	19
1952	30
1953	42
1954	77
1955	120
1956	150
1957	190
1958	230
1959	280
1960	330
1961	380
1962	430
1963	500

Nevertheless, it seems that for the first time in history, there are sheet materials becoming available which are about as cheap as paper on a coverage basis and which have sufficiently good properties to enable them to compete for certain specific markets with paper. However, it is important that my statements be viewed in the proper perspective. We are certainly not predicting, at least I am not, extremely heavy invasion of the paper markets by the plastic films. Though the absolute numbers may be large (in pounds), they are relatively small on a percentage basis and also small in tons. Specifically, the total sales of polyethylene films and film products in 1959 were only about 300 million pounds or 150 thousand tons (Table I). This figure, while impressive in absolute numbers and particularly impressive to the chemical industry that is normally used to much smaller numbers, is really quite trifling when compared with the total U. S. paper output of over 20 million tons. Further, the total predicted growth rate of polyethylene film in the United States is presently about 50 million pounds per year. This would mean that the 1965 polyolefin film business would amount to about 600 million pounds or 300 thousand tons. This is only 1.5% of the paper industry.

Fundamentally, there is nothing on the horizon in the plastic film industry, to my knowledge, which will enable it to compete with paper in the bulk of applications for paper where great strength, stiffness, absorbency, or permeability are required attributes. The only applications in which plastic films can compete with paper are those in which a much thinner sheet will do the job, that is, those cases in which paper is "overspecificationed" for the job. Thickness reduction is the only way by which the higher material

Table II. Projection of Polyethylene Markets for 1961

Consumer	*Millions of pounds*
Bakery	60
Produce	115
Soft goods	16
Dry cleaning	35
Agric. bldg. & construction	70
Paper goods	10
Poultry, meat, dairy, hardware, etc.	20
Consumer prod.	20
Rubber	7
Furniture	8
Glazing	1.5
Export	9
Auto	5
Total	376.5

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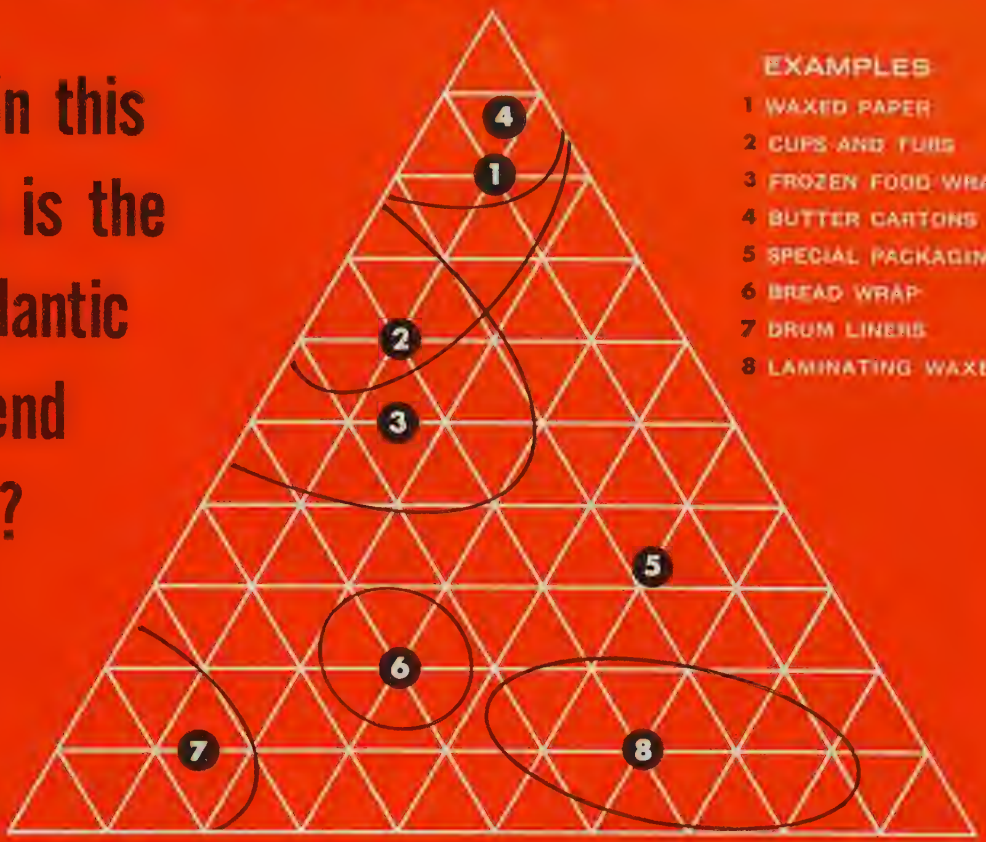
Where in this triangle is the best Atlantic wax blend for you?



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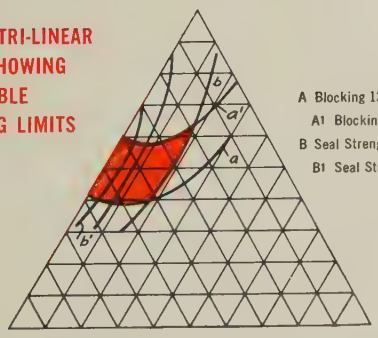
As an example, wax coated wrappings for frozen foods must furnish good blocking resistance for easy handling and stacking . . . strong heat seal to retain freshness and flavor . . . low moisture vapor permeability . . . and attractive high-gloss appearance. The characteristics of each component in such a coating would be plotted on the chart to form the envelope-shaped area indicated here in red. Any proportion of the waxes within this area may be satisfactory for frozen foods packaging.

TYPICAL TRI-LINEAR CHART SHOWING ACCEPTABLE BLENDING LIMITS



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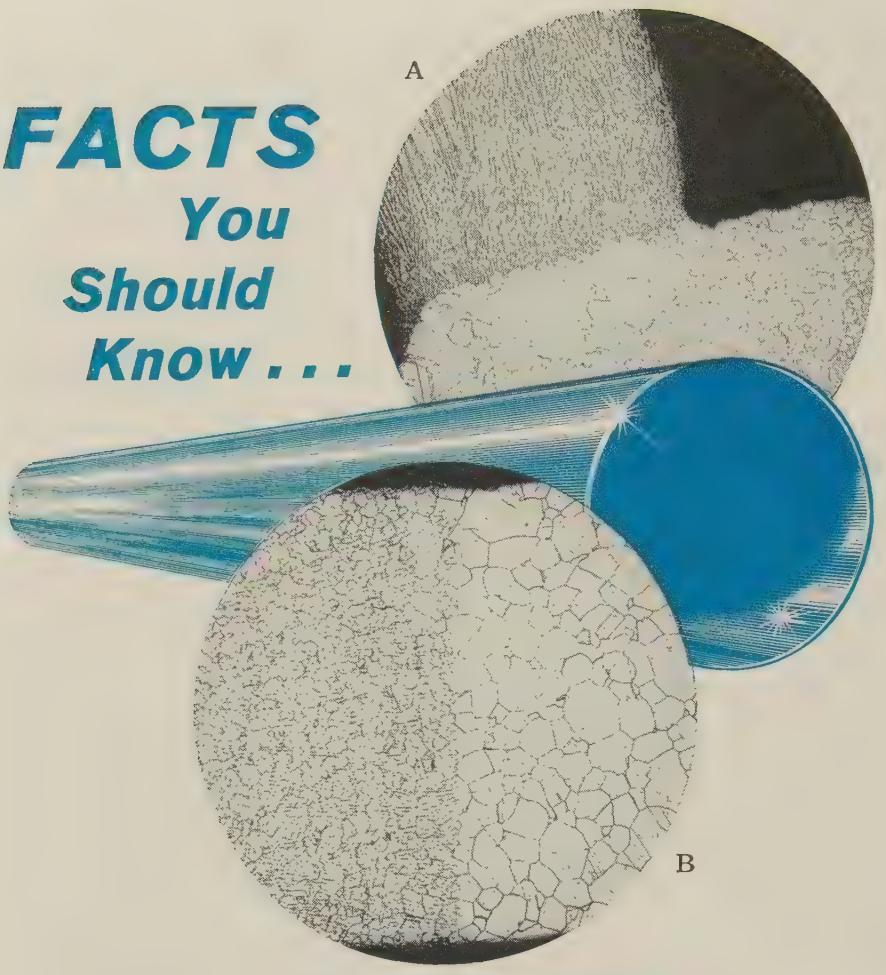

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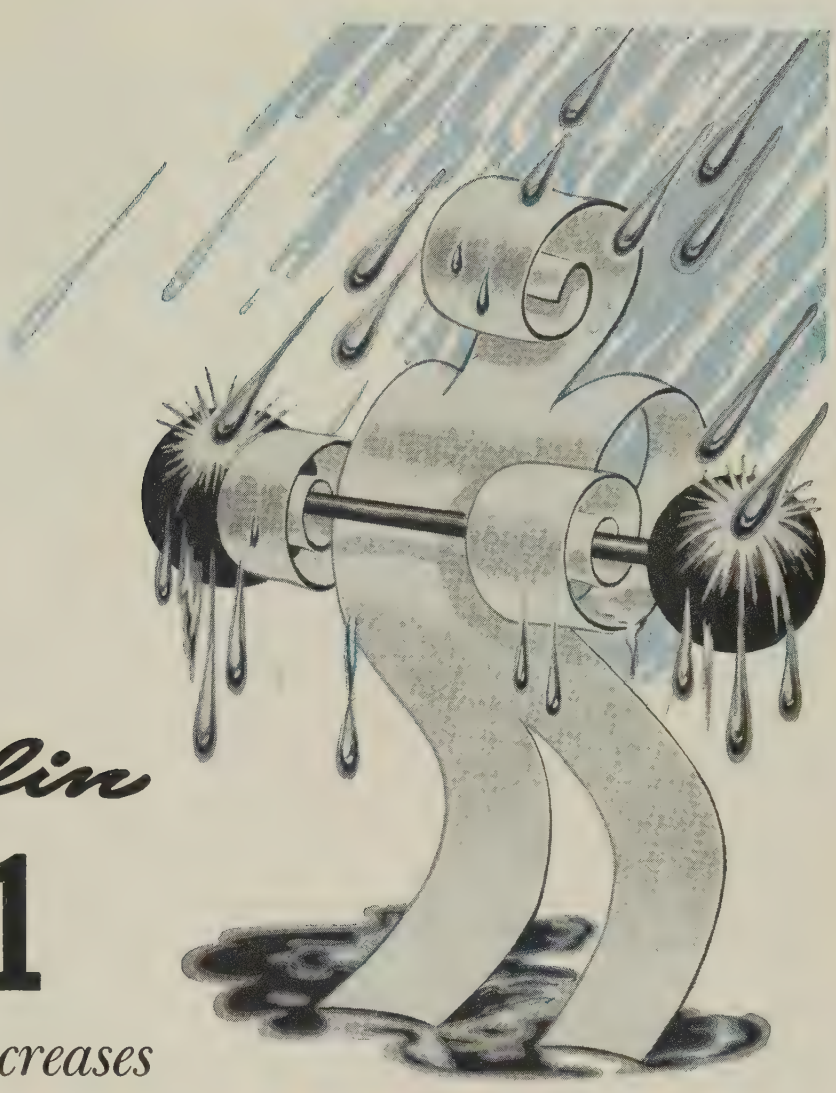
cost of the plastics can be compensated. The bulk of 50 million pounds per year of film sales growth is in areas not presently occupied by the paper industry. For example, there are entirely new markets particularly suited to polyethylene films such as those for pond and ditch liners, silo covers, temporary silos, temporary protective coverings for building materials and workmen, further growth in produce bags and similar items. It is only in the specialty overwrapping market where one would expect substantial invasion of the paper industry by plastic films, and in this area only in specific applications.

Further, the advent of new, low cost films such as polyethylene and polypropylene are expected to have a beneficial effect on markets for paper. As one example, the enormous market for liquid containers, not now enjoyed by either the paper or the plastic film industry, might be opened up by the successful development of the paper box-plastic bag combination. This particular project has been worked on by several companies, but to my knowledge, the remaining problems have not yet been solved. These problems, however, do not appear insoluble, in my opinion. Another example, is the opportunity presented by the prospect of having a cheap film as strong as Mylar to laminate with paper.

Thus, I would be surprised if the net effect of the burgeoning plastics film industry on the paper industry will be negative; quite the contrary, I think it is quite possible that it will be positive. Of course, it will be necessary for the paper industry to do sufficient product development work to capitalize on such opportunities which may be presented, such as those just mentioned. Along this line, you may be interested in the extent of product and process research now under way in the plastic film industry. Historically, this industry has done very little research, largely because it was an industry made up of very small companies. During the last few years, however, leaders have emerged who have found it necessary to become associated with very large chemical companies in order to achieve an adequate financial base for the rapid



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growth necessary in this field and to eliminate the inefficiency inherent in a multistage production and distribution system. Concurrently, with this vertical integration movement, research on plastic film has been accelerated greatly. Thus, we now have the picture of not only vast and complex chemical plants and heavy research and development effort aimed at new polymers and cheaper processes for making them, but we also have the picture before us of almost equally complex, large scale, film-making plants and equally heavy research and development effort aimed at cheaper, stronger, and generally better films and film products. The results of these heavy research and development efforts have not yet appeared on the market place, since this is a relatively recent development and lead time is long. However, they may be expected to appear in 1960, 1961, and 1962 in the form of new film and film products from companies such as Du Pont, Union Carbide, Dow, American Viscose, and Sun Oil, National Distillers, and others. It is likely, therefore, that late entries into the race for the cellophane markets will be at a considerable disadvantage, particularly since these companies have such massive technical power in being. They also have a very considerable lead time.

In summary, therefore, one might draw the following conclusions:

1. The bulk of the projected growth of the plastic film industry is in entirely new markets not presently occupied by paper or will be at the expense of cellophane.
2. Plastic films, however, may be expected to invade certain paper markets wherein transparency and toughness are desirable and limpness is either tolerable or desirable.
3. Complex new films of greater strength and stiffness will be coming into the market place in the next few years and may make obsolete present films in these markets. These have been under development for several years in the largest chemical companies in the country.
4. Even though some paper markets may be invaded by film, other even larger markets will be opened up by combination of paper products and films.
5. Plastic films will displace only an extremely small fraction of the total U. S. paper market, perhaps no more than 1%.

I think this concludes my formal talk. I shall be glad to answer any questions anyone may have during the discussion period.

Presented at the Fourteenth Plastics-Paper Conference of the Technical Association of the Pulp and Paper Industry, Chicago, Ill., Sept. 20–23, 1959.

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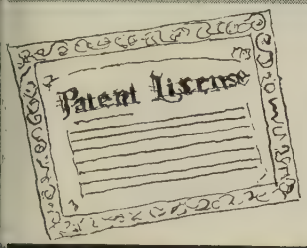

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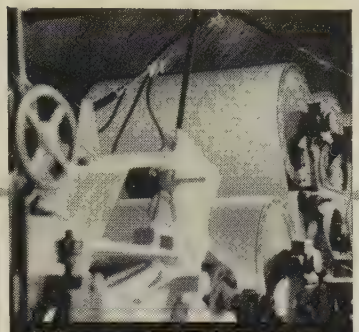

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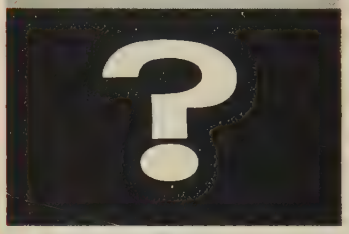

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- ☐ Peroxygen Chemicals
- ☐ Persulfate Chemicals
- ☐ Please have a Sales Engineer call.

NAME_____
FIRM_____
ADDRESS_____
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BECCO fmc

BECCO CHEMICAL DIVISION, FMC
Station B, Buffalo, New York
Dept. T-C

Gentlemen:
We **would** like help with our pulp. Please have a Becco Sales Engineer call.

NAME_____
FIRM_____
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CITY_____
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BECCO fmc

BECCO CHEMICAL DIVISION, FMC
Station B, Buffalo, New York
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Gentlemen:
Please tell me more about your Four-Fold Engineering Service.

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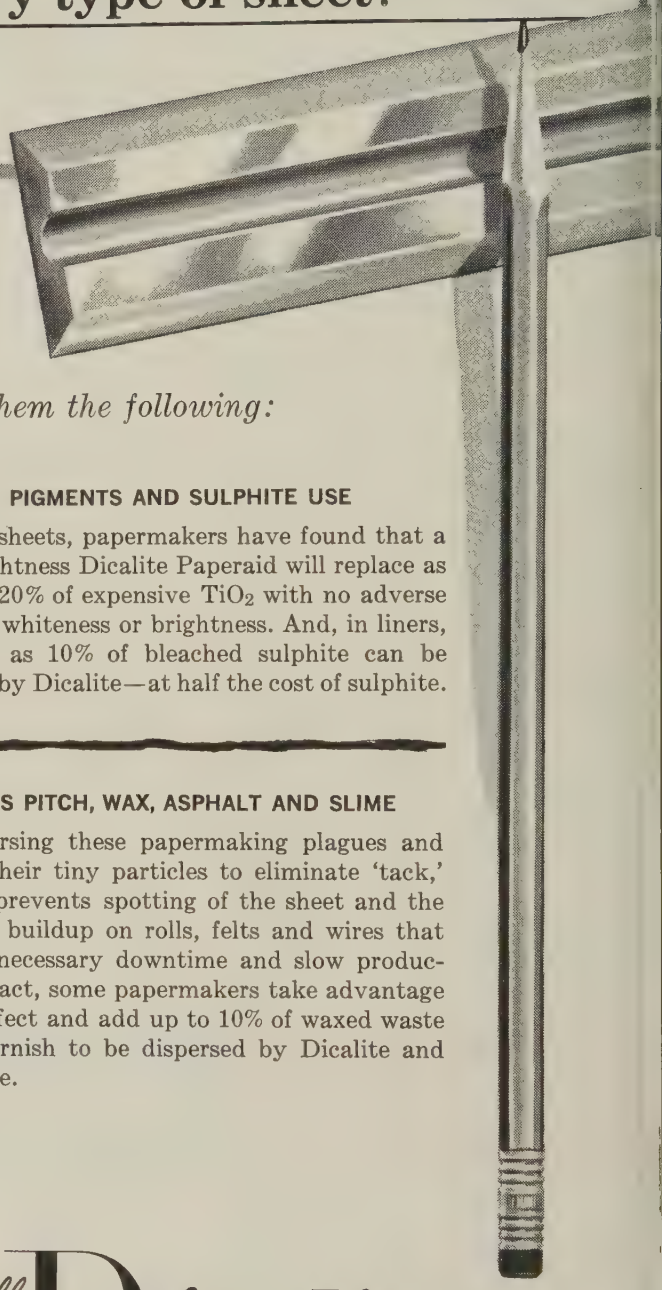
Let's get this straight!..

Dicalite Paperaids can do all these things

...but Not all of them in every type of sheet!



Definitely, Dicalite is not offered as a panacea, good for everything. But many leading papermakers find Dicalite Paperaids a very valuable aid in several different ways—among them the following:

IMPROVES SHEET FORMATION

By promoting more even dispersion of fine fibers and pigments, Dicalite gives a better sheet... more even, fewer thick and thin spots...better opacity...a smoother surface for improved printability or finer finish when laminating with foil or liners.

EXTENDS PIGMENTS AND SULPHITE USE

In some sheets, papermakers have found that a high-brightness Dicalite Paperaid will replace as much as 20% of expensive TiO_2 with no adverse effect on whiteness or brightness. And, in liners, as much as 10% of bleached sulphite can be replaced by Dicalite—at half the cost of sulphite.

GREATER BRIGHTNESS AT LOWER COST

More high-brightness Dicalite (90 or better on the G.E. scale) is retained in the sheet than any other extender or pigment such as clay and TiO_2 —3 times as much, by actual controlled paper mill tests on a top liner sheet. Within limits, Dicalite Paperaids are your cheapest way to a brighter sheet.

CONTROLS PITCH, WAX, ASPHALT AND SLIME

By dispersing these papermaking plagues and coating their tiny particles to eliminate 'tack,' Dicalite prevents spotting of the sheet and the excessive buildup on rolls, felts and wires that cause unnecessary downtime and slow production. In fact, some papermakers take advantage of this effect and add up to 10% of waxed waste in the furnish to be dispersed by Dicalite and act as size.

Space prevents listing all the advantages of Dicalite Paperaids, but your Dicalite man can give you the full story.

Dependable GLC GREAT LAKES Dicalite®

PAPERAIDS

DICALITE DEPARTMENT, GREAT LAKES CARBON CORPORATION • 612 S. FLOWER ST., LOS ANGELES 17, CALIF.

WATER COLOR PAINTING BY L. J. A. NEESE, 1959

SNOW SCENE: Viewed from wintry skies, Beloit Iron Works sparkles and steams in the crisp Wisconsin air, its foundry flames leaping, its power-house stack trimmed with multicolored lights. The artist's aerial view, from high above the Beloit College campus, shows the plant's 17-acre site on the Rock River, at Beloit, Wisconsin. From here, since 1858, have come world-renowned Beloit paper machines.

BELOIT IRON WORKS · PAPER MACHINERY · BELOIT, WIS., U.S.A.

B.C. Forest Service Photo

PROMISE HIGH QUALITY BLEACHED PAPER PULP IN 1961

Early in 1961, a new high quality market pulp mill will go on stream near Castlegar, British Columbia, at the foot of the Arrow Lakes region of the Columbia River. Celgar Limited will utilize almost 900,000 acres of prime northern-type forest lands held under a Tree Farm Licence in perpetuity.

All the resources necessary for efficient mill operation are available — wood to meet any future demand, plentiful water from the clear Columbia, power and gas, transportation from the mill site to markets, and trained people from established industrial communities in the area.

Celgar Kraft will combine many of the best qualities of Northern and Western pulps to produce a product with an exceptional balance of properties. The long, tough fibres from high-density softwoods develop high bursting strengths coupled with outstanding tear resistance over a wide range of freeness, and in a variety of stock preparation equipment.

V4247-1

COLUMBIA PULP SALES LIMITED has been formed to distribute Celgar Kraft pulps and Columbia Cellulose sulphite pulps. Offices are located at:
1030 West Georgia St., Vancouver 5, B.C.
1600 Dorchester St. West, Montreal 25, P.Q.

Celgar Kraft

Plastic Coated Papers—Present and Future

JOHN V. ELLER

I EXERCISED my prerogative as chairman of this session to reserve for myself the opportunity to discuss the present and future of plastic coated papers. This segment of manufacturing endeavor has had a dynamic growth in the past 10 years. It is a success story best illustrated in terms of a few figures.

In 1940 the amount of plastic coated paper available for any use was so small as to be insignificant. In the decade to 1950 the first polyethylene coated papers were just appearing in the market place, again in insignificant amounts. In the dynamic decade between 1950 and 1960, a period just closing, this volume has grown to the point where we are now consuming approximately 30 million pounds of polyethylene alone in extrusion coating of paper and paperboard. This figure is small in terms of the torrents of plastic now issuing from the chemical industry. In view of the size of the markets just beginning to be explored and exploited with polyethylene coated paper and paperboard, it is not unreasonable to expect that the annual consumption of polyethylene in extrusion coating will approach 150 million pounds by 1965. This is an increase of five fold. Since many of these new markets will involve the use of plastic-coated board it is not unreasonable to expect an increase in the use of paper and paperboard by tenfold in 1965.

What triggered this tremendous growth in the use of plastic coated paper? The answer lies in a combination; the introduction of polyethylene coating, and the healthy appetite of the consumers for better packaging materials.

Polyethylene burst on the imaginations of men in the packing industry. Here was material which would fulfill the dream of a barrier coating that functioned under normal temperature extremes, would withstand creasing and handling without significant loss of barrier, promised economy, was greaseproof and waterproof, was sterile and odorless and was heat sealable. In fact, this might be the universal barrier coating, which overcame, in one giant step the shortcomings of wax, phenolics, vinyls, and the like. Time and experience have mellowed our understanding of the barrier properties of polyethylene as a coating but the disclosures have been for the most part favorable.

The exciting race to develop coating techniques for this new material, polyethylene resulted in the development of an entirely new coating process—extrusion coating. This was done at the expense of the older techniques of calender coating and solvent solution cast coating. The calender coating process still enjoys a limited outlet for special applications but the extrusion-coating process has become predominant.

The term *plastic coated papers* has become *polyethylene-coated papers* in the packaging field. I believe that the future expansion of plastic coated paper will be primarily in this area.

JOHN V. ELLER, Technical Director, H. P. Smith Paper Co., Chicago, Ill.

The easiest way for me to elaborate on my earlier predictions will be to review a few specific areas of application of polyethylene coated papers and paper boards and indicate their growth potential.

A number of very large applications for polyethylene-coated papers and paperboards have been held back because the existing processes require that the components be gluable in an overlap joint. A further complication has been the requirement that these glue joints be made with existing equipment, using low cost adhesives such as dextrin, and at speeds comparable to present production rates. Recently developed processes for treatment of the polyethylene surface have overcome most of these obstacles. These treating processes are relatively low cost in terms of equipment investment and do not restrict the extrusion-coating operation. They can be performed in line with the coating operation; in later finishing operations, or in the consumers assembly operation.

One example is the multiwall bag. The use of a barrier lining is required in approximately 30% of all multiwall bags and is desirable in a much larger percentage. The potential here for polyethylene coated liners is estimated at approximately 70,000 tons per annum. Until recently the penetration of polyethylene-coated papers into this field, as the barrier lining, was limited by the high cost of pressure sensitive adhesives or hot melt adhesives required at the side seam, and the impracticability of making glued bottom closures. Use of these special, high cost adhesives usually involved installation of additional equipment and resulted in some loss of production. The side seam and bottom closures can now be made on existing equipment, using low cost adhesives at standard production rates. This will allow the polyethylene-coated paper lines to compete for this huge market on a more equal basis with the traditional asphalt laminated papers.

An even larger potential exists in the carton and container field. Limited amounts of polyethylene coated board are in use in direct competition with greaseproof, wax laminated construction at the present time. The ability to furnish a gluable flap closure which can be processed on conventional equipment will open this potentially large market for the polyethylene-coated board. The improved appearance plus the improved water and grease resistance of the polyehylene coating will offer the industry a superior material for their customers.

Another application for a treated polyethylene-coated board has been in the automotive field. In this case the polyethylene-coated board is replacing an asphalt-laminated product.

These examples represent only a few of the opportunities which exist for a gluable polyethylene-coated paper or paperboard.

A further application for polyethylene-coated papers and paperboards which has recently been introduced,

UNIQUE direct tank-mounted
LIQUID LEVEL TRANSMITTER

converts measurement directly to 3-15 psi air signal

Exclusive static pressure connection for closed vessels above or below atmosphere . . . eliminates need for second instrument.

This sensing diaphragm capsule flange-mounts directly on side of tank. All wetted parts of Type 316 stainless steel, with optional plastic coating for further corrosion protection.

IDEAL FOR: Blow tank level – Brown stock washer filtrate tank level – Stock level and seal boxes – any pulp or paper mill fluid

Now you can measure the level of any "difficult" or easy-to-measure fluid — economically, without the complication of floats or bubble tubes, and with *sustained high accuracy over the entire range span.*

Flange-mounted directly to the side of an open or closed tank, the Type 13FA Transmitter eliminates piping and purging. Its stainless steel diaphragm capsule senses level changes instantly. Conventional tubing leads its output air signal directly to standard 3-15 psi receiver-recorders and controllers without need for intermediate signal converters.

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LIQUID LEVEL TRANSMITTERS

is that of the polyethylene extrusion-coated milk carton. This application, though introduced in Europe, is rapidly gaining acceptance here, and could become the largest single extrusion-coated product in the industry.

If we look at the economics of this construction, it becomes apparent that polyethylene-coated board compares favorably with that of the present waxed grades. The advantages are numerous. The polyethylene-coated carton has greater resistance to leakage, handling damage, chipping, and further eliminates wax-chip contamination of the milk. This carton can be tightly heatsealed on inexpensively modified, conventional, carton equipment. An interesting possibility is that this type of container will fit into the beverage packaging field. At present a number of products such as juices and other noncarbonated beverages are packaged in waxed containers, and like milk and cream, can use the polyethylene coated carton.

The development of a more greaseproof copolymer, or the substitution of another plastic coating, may be the long awaited opening into the oil packaging field.

Extensive inroads have been made into the market for utility waterproof wrapping paper. The introduction of polyethylene-coated paper as a frozen food locker wrap met with immediate success. The functional properties of polyethylene have given outstanding performance in this field and this new product is gradually replacing the wax-coated and wax-laminated papers. As further improvements are made in the properties of the polyethylene coating it will become more difficult for waxed paper to maintain any position in this field.

The convenience packaging of metal parts, originally explored by the Government, is being extended into many commercial applications. This trend will continue because Mrs. America demands it. The replacement of waxed and asphalt-laminated papers is also going forward in such diverse applications as paper mill roll wraps, nursery wraps, bulk meat storage, and low cost temporary tarpaulins for construction materials.

Now here are a few things the paper industry and the plastics industry are doing to insure this growth.

A fairly recent innovation in the plastic field is the development of high density polyethylene suitable for extrusion coatings. Our laboratory test results indicate that these products have markedly improved grease and oil resistance. In addition to this, improved slip characteristics, superior stiffness, increased abrasion resistance and puncture resistance will generate a line of products not obtainable with conventional low density polyethylene coatings. The possible fields into which this type of coating will expand are of course speculative. However, it does present a tool which will allow polyethylene paper and paperboard further encroachment upon packaging media such as the metal cans and for applications where sufficient resistance to fats and oils are not presently obtainable with low density extrusion-coated papers and paperboards.

Considerable progress has been made in the extrusion coating of pigmented polyethylenes. The coated products are interesting in that they also have the possibility of invading markets which presently are using inks and other pigmented coatings without barrier properties. Here again we have the advantages of the polyethylene combined with a wide range of pigments to enhance an already existing product and the possibility of creating new products. Pigmented polyethylene extrusion coatings to a limited degree are currently being used in the automotive, insulation facing industries, and the bread wrap field. Products of this type may also find applications in the closure and decorative fields. It will also serve as an overcoating of low cost paper and paperboard which are normally not suitable in clear extrusion coating due to their appearance. This will permit the upgrading of these products to compete with much higher cost bleached board construction.

Another interesting possibility, not yet exploited is that of using the pigmented polyethylene-coated products as a means of identification.

One of the real problems in the extrusion coating of paper and paperboard has been the difficulty of obtaining good adhesion between the plastic and the paper at high speeds. Papers which readily lend themselves to good adhesion impair the barrier properties of the plastic coatings. The paper industry has made a considerable contribution in the development of finishes and special sizings which has materially reduced this problem.

More contributions are forthcoming from these industries.

I feel very much like the prospective young bridegroom on the eve of his marriage and I look at the next five years with a great deal of immediate enthusiasm but with some reservations about the long nights ahead. To meet the challenge of the great opportunities for expansion of markets for plastic-coated paper and paperboard we will need the assistance of every segment of the industry. We need the active help and understanding of the packaging equipment manufacturers. We need all of the technical and marketing advice we can get from the plastics and paper industries as we explore the nylons, the polypropylenes, the polystyrenes, the polymers "X," the polymers "Y," the polymers "Z," the stretchable papers, and other products still in their laboratories.

Presented at the Fourteenth Plastics-Paper Conference of the Technical Association of the Pulp and Paper Industry, Chicago, Ill., Sept. 20–23, 1959.

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of the

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of the

Pulp and Paper Industry

Hotel Commodore

New York, N. Y.

Feb. 22–25, 1960

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upgrades packaging board to premium quality...at far less than premium cost

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If you make packaging board, it will pay you to investigate Colton's new Flexac series of homopolymer polyvinyl acetate emulsions for upgrading print base coatings.

Flexac, a giant step ahead for the expanding boxboard industry, is a synthetic polymer offering the ultimate in light stability, a highly-desirable lower odor level and good pick resistance . . . at a price substantially lower than that of comparable-quality binders.

You and your customers are naturally interested in printability. The ready-to-use Flexac series has been developed to provide unexcelled printability . . . and machinability as well.

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AT THE FRONTIERS OF PROGRESS YOU'LL FIND . . .

AN AIR REDUCTION PRODUCT

The Present and Future of Gummed Papers

H. R. SCHWAPPACH

GUMMED papers represent a basic commodity serving both the packaging and graphic arts industries and amounting to a total annual sales of $200 million. Without gummed products, both these industries would be significantly changed and many of the end products, as we know them today, would be either nonexistent or economically prohibitive.

Gummed papers represent one of three major areas of precoated adhesive sheet products. The other two are heat-seal and pressure-sensitive coated materials.

Classically, gumming formulations are based on glues, dextrins, and combinations of the two. In more recent years, the development of water soluble polymers has found application in water rewettable adhesive systems.

The major advantage of gummed adhesives is cost. Dextrin raw materials range from 8¢ to 13¢ per lb., glues from 15¢ to 40¢ per lb. and water soluble polymers from 50¢ per dry lb. on up. These materials individually, or in combination, can furnish the most economical balance of adhesion properties for any given application.

The three basic requisites of gumming formulation are adhesion, blocking resistance, and flatness. Gummed papers are designed to adhere to a wide variety of surfaces including paper, boxboard, cloth, glass, steel, brass, ceramics, plastics, rubber, wood, and a number of others. The speed of adhesion required may vary from less than 1 second to $^1/_2$ minute or more. After drying, a permanent, rigid bond is established under normal application conditions.

In opposition to adhesion requirements, gummed papers must be designed with adequate "blocking" resistance so that they will arrive at the point of application in a usable condition. This is particularly true in gummed label products where smoothness of the printing surface is critical.

A further requirement of gummed papers is flatness through a wide range of relative humidities. This property relates to ease of handling in both roll form and sheet form. In printing operations, for example, a curled sheet product can result in poor printing quality, inefficiency, or even press shutdown. The curl versus relative humidity relationships are therefore of prime importance in many applications.

All water rewettable adhesive combinations exhibit some degree of curl problem. The conventional approach to attain flatness is "breaking"—a process of mechanically fracturing the gumming surface into small adhesive particles. A new development in gummed label products involves a unique formulation and coating process which eliminates breaking and results in greatly improved curl stability.

Other adhesive characteristics of lesser importance include odor, taste, gloss, color, etc. Adjustment of these properties are achieved by proper selection of the base raw materials plus the use of minor additives.

There are three major product lines in which gummed papers find application: (1) sealing tapes; (2) label papers; and (3) box tapes. Gummed sealing tapes are used in many packaging functions, primarily carton closures and bundle wrapping.

There are two general classes of sealing tapes, namely paper tapes and reinforced tapes. The paper type is used in the six strip method of sealing. The most common backing is 60-lb. natural kraft although a variety of weights and colors are also available.

The reinforced sealing tape backing is a kraft-adhesive-kraft sandwich reinforced with glass or rayon yarn. It is normally applied in a two strip method of sealing and, as such, is commonly applied with automatic tape sealing equipment.

The current total market for gummed sealing tapes is approximately $45 million annually with an anticipated growth to $55 million in the next five years.

Competitive methods of carton closing include the use of wet case sealing adhesives, staples, pressure sensitive sealing tapes, twine, etc.

Gummed label papers have almost unlimited applications in product identification, shipping information, advertisement, sales promotion, publicity, directions for product use, trading stamps, philanthropic stamps, business forms, and so forth. A wide variety of backings are produced, including cast coated, lithos, machine finished, supercalendered, plated, krafts, and many specialty papers in a complete color range.

The adhesive coatings are divided into two general categories, namely strong glue and dextrin. Strong glues are designed for more rugged adhesion performance to a wide variety of surfaces. Dextrin types are directed toward simpler adhesion requirements primarily to paper, paperboard, and other porous surfaces. The dextrin label is frequently activated by licking with the tongue and therefore must be acceptable in toxicity, taste, and odor.

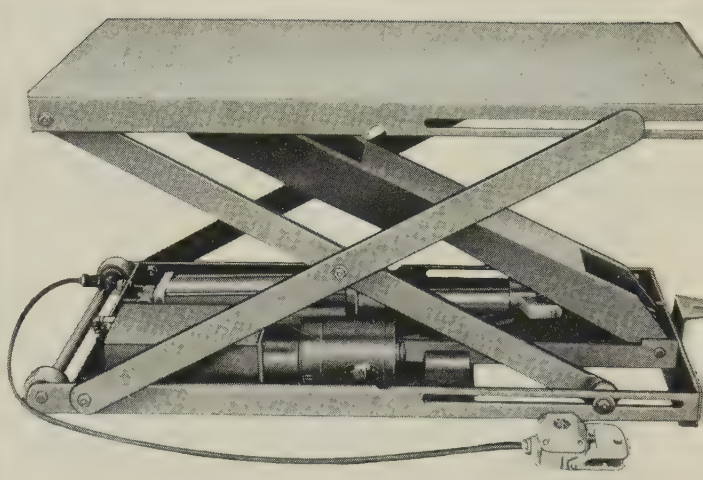
The current total market for gummed label products is $25 million with an anticipated growth to $33 million by 1965.

Box tapes provide a strong economical closure for the manufacturers joint on corrugated and fiberboard containers. Over a period of years, high-speed taping equipment has been developed which automatically feeds, folds tapes, and stacks carton blanks. To service this industry, there are over 20 different types, weights, and strengths of box tapes, including heavy kraft liners, cloth-paper laminates, kraft sandwiches reinforced with glass, rayon, nylon, and sisal fibers. The greatest volume of box tape is represented by the glass reinforced kraft sandwich. This is produced with both asphaltic and nonasphaltic laminating adhesives.

H. R. SCHWAPPACH, Technical Director, Mid-States Gummed Paper Co. Division, Minnesota Mining and Manufacturing Co., Chicago, Ill.

CUT PRODUCTION COSTS with a SCISSORS

to be exact...



with the Stevens "sizzer lift"

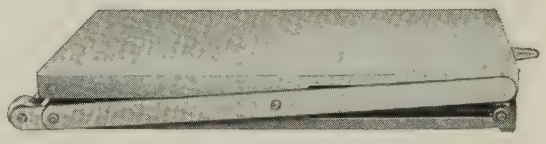
Smooth action– no jerks or jolts with the Stevens "sizzer lift"—either up or down. Whatever the working height, you can be sure that the load unit will be positioned quickly and easily.

Positive control– by a single foot pedal or hand switch. Whichever method is best for your operation, you can count on positioning accuracy (up or down) with the Stevens "sizzer lift."

Safety– sturdy center beam elevation plus orifice-controlled feedback, helps prevent accidents and lost man-hours. Workmen trust it!

Rigidity– the Stevens "sizzer lift" keeps loads in balance—even when off center. The scissored side supports provide perfect nesting and steady, level lifting and lowering.

Starts low– from seven inches off the floor, the Stevens "sizzer lift" raises a full capacity load—smoothly, easily, gradually, to work height.



Lifts high– there's no holding back when the "sizzer lift" has a work load under control. Easily up—easily down—exactly the way it should.

Portable - retractable - flush mounted - recessed – whichever type of installation is needed, you will find a Stevens "sizzer lift" model that meets the need—with varying sizes, varying capacities, varying lift heights.

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Standard of FINISHING

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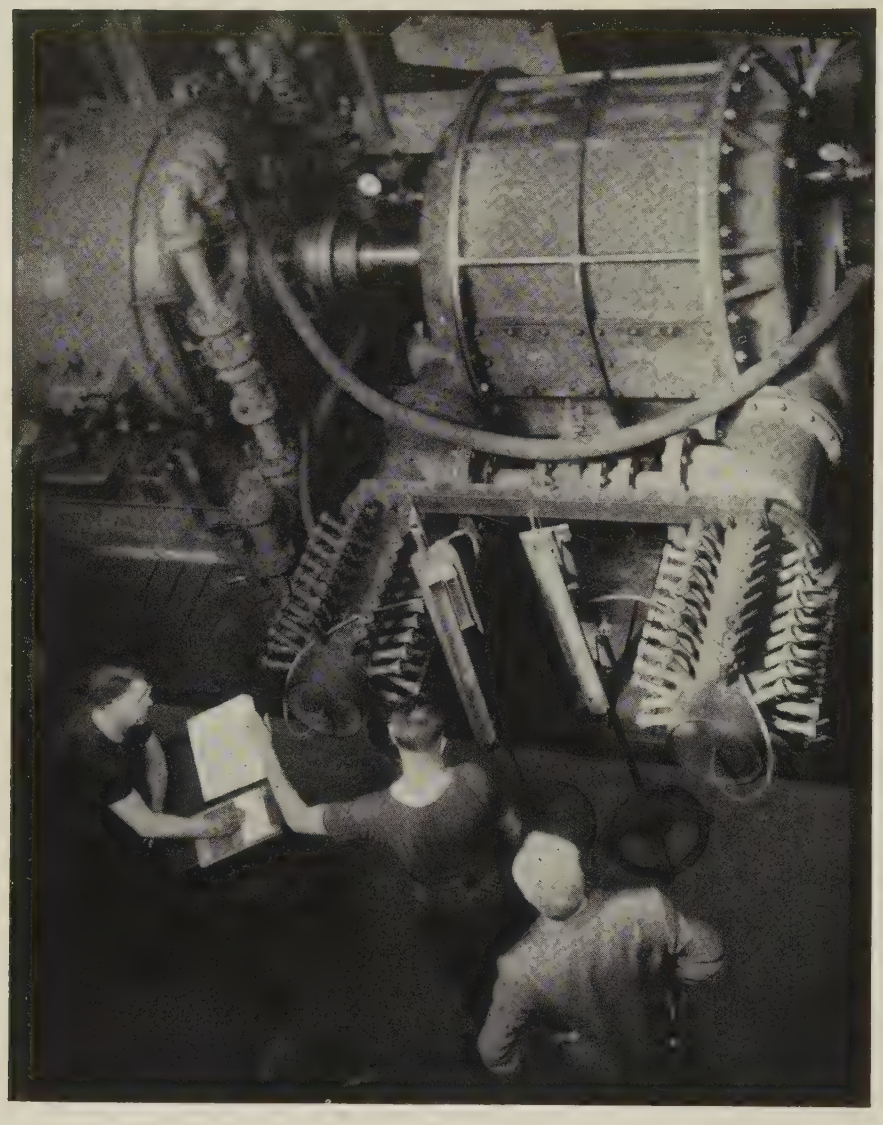

Rated capacities of Nash Vacuum Pumps are not theoretical. Every Nash Pump is tested individually. Air capacity is determined by delivery thru accurately machined and calibrated orifices. Related vacuum is measured by precise mercury column, and horse power is recorded electro-dynamically. Records of these tests are retained by us, and certified copies are available to Nash Pump owners.

That is one of the reasons why Nash Vacuum Pumps are installed in over a thousand leading Paper Mills. An engineer from Nash will be glad to survey your mill, and make recommendations, entirely without obligation to you.

NASH ENGINEERING COMPANY

440 WILSON ROAD, SO. NORWALK, CONN.

The boxboard industry uses about $17 million worth of box tape annually. This field is expected to grow to $21 million by 1965.

Competitive methods of forming boxboard containers include wire stitching and the use of wet adhesives.

Aside from the three major product areas previously mentioned, there are a number of miscellaneous applications for gummed papers. Dielectric tapes are used in the electronic industry. Veneer tapes service the furniture industry and building trades. Teletype tapes assist in communications. Meter mail tapes have provided automation in postal activities. Bookbinder tapes service the publishing houses.

In conclusion, gummed papers represent one of the oldest factors in the paper converting industry. They are a basic commodity in many growing industries and will continue to contribute to the fields of packaging and graphic arts.

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For surface sizing paper or board, water soluble GELVATOL resins offer dramatic increases in strength, transparency, grease resistance and printing qualities. Can be applied by any of the conventional methods: tub, size press, and calender stack.

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Increased Strength. GELVATOL sizing significantly increases the Mullen and fold endurance of rag stock and other high quality paper.

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Increased Grease-Resistance. Surface sizing with GELVATOL makes paper grease-resistant; surface coating makes paper grease-proof. Improves wax holdout.

Increased Printability. GELVATOL imparts a smooth finish to paper. Improves ink holdout and contrast. Provides excellent varnish holdout.

GELVATOL is available in a wide variety of grades. Whatever your sizing needs it will pay you to write for full technical information to Shawinigan Resins Corporation, Department 6212, Springfield 1, Massachusetts.

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Inconel alloy stops clogging in blow condenser

Clogging of tubes stopped. Substitution of Inconel alloy for carbon steel in the tubes of this blow condenser stopped clogging. Inconel alloy has shown outstanding resistance to attack by black liquor and to chloride ion stress corrosion cracking.
Photo courtesy of Champion Paper and Fibre Company

No clogging after 1½ years of service . . . No appreciable attack by black liquor or chlorides.

Every 20 minutes this condenser takes a blow from one of 9 digesters at the Pasadena, Texas plant of Champion Paper and Fibre Company.

When made of mild steel, the condenser tubes had to be cleaned a number of times a year. Corrosion of the tubes provided a rough surface where insoluble organic matter could attach and rapidly clog them. And the tubes lasted 24 months at most.

Still no clogging of Inconel alloy tubes

When Champion installed Inconel* nickel-chromium alloy tubes early in 1958, the results were quite spectacular. There has been no clogging of condenser tubes to date. The splendid corrosion resistance of Inconel alloy provides a smooth surface where insoluble organic matter cannot readily adhere.

After 1½ years of service these Inconel alloy tubes show no significant corrosion on either side. On the shell side, they withstand slightly alkaline vapors at 230°F and 5-10 psig. Vapors contain sodium hydroxide, hydrogen sulfide, sodium sulfate, sodium sulfide, turpentine, methyl mercaptan, and dimethyl sulfide. On the water side, 75 ppm of chlorides and 8.3 ppm of oxygen have caused no trouble.

To select the right materials for your pulp and paper application

To help solve your corrosion, sliming, contamination or wear problems, we maintain a large file of technical data. Write to us now for information on any metal problem you may now have, or anticipate.

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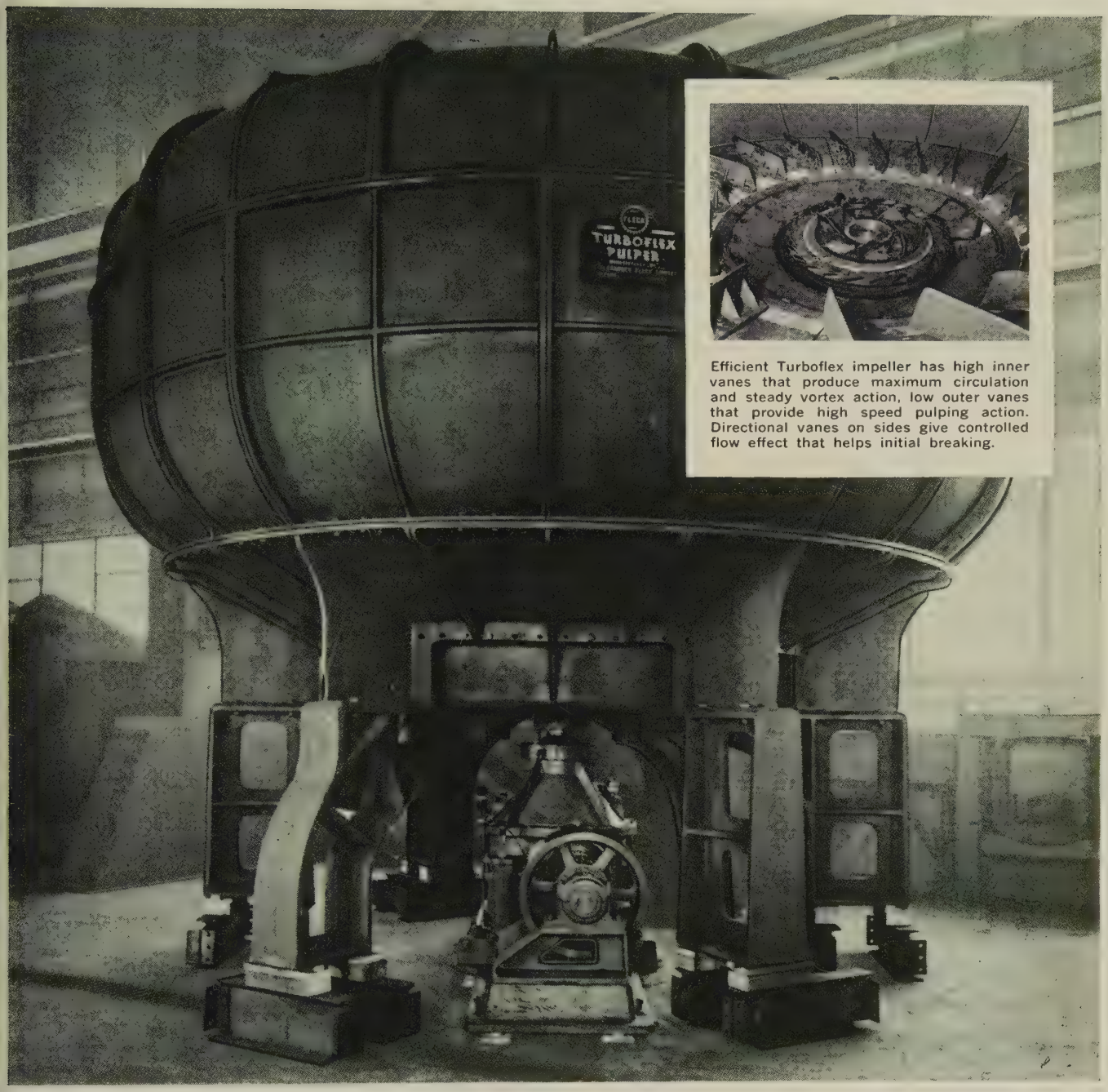
INCONEL®

For more efficient waste paper pulping
Take a look at Turboflex



Efficient Turboflex impeller has high inner vanes that produce maximum circulation and steady vortex action, low outer vanes that provide high speed pulping action. Directional vanes on sides give controlled flow effect that helps initial breaking.

Proven in Canada by Fleck – Now built in the U.S. by Jones

With more than two decades of experience in Canadian and European mills the Fleck Turboflex pulper has earned recognition as the finest equipment of its kind available anywhere. To provide American mills with the same top efficiency in waste paper pulping, Turboflex units of all sizes are now also being built in the U.S. by Jones.

Some of the features you will prefer in Turboflex include: *curved tops* to prevent serious splashing; *specially designed impellers* for more effective defiberizing; *disc type dump valves*, instead of slide, for faster discharge; *replaceable wearing* parts for faster, lower cost maintenance.

For complete details on Turboflex write to E. D. Jones Corporation, Pittsfield, Mass.

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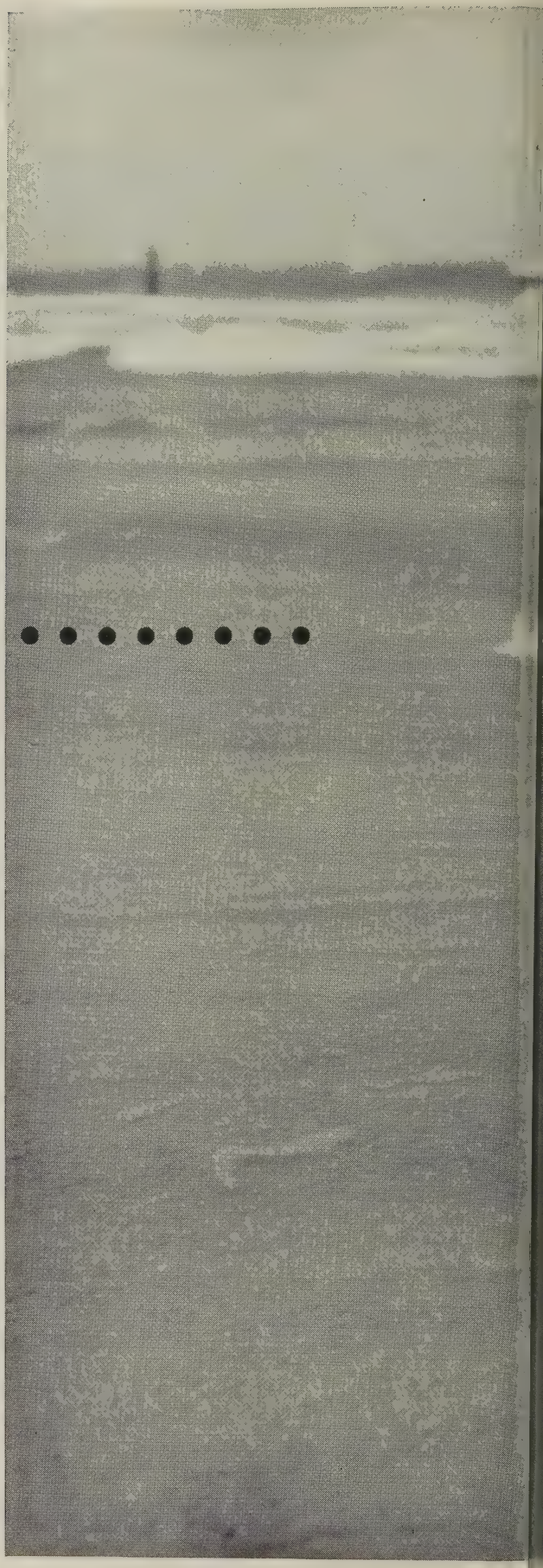
PULP MILL EQUIPMENT AND
STOCK PREPARATION MACHINERY



Foam is fun.....

but not for paper coaters

Koppers has just developed DYLEX® K-54 latex for paper coaters—a brand new latex, when agitated, produces a minimum of foam which dissipates at a rapid rate. A critical series of tests between DYLEX K-54 and other competitive latices has proved this conclusively.

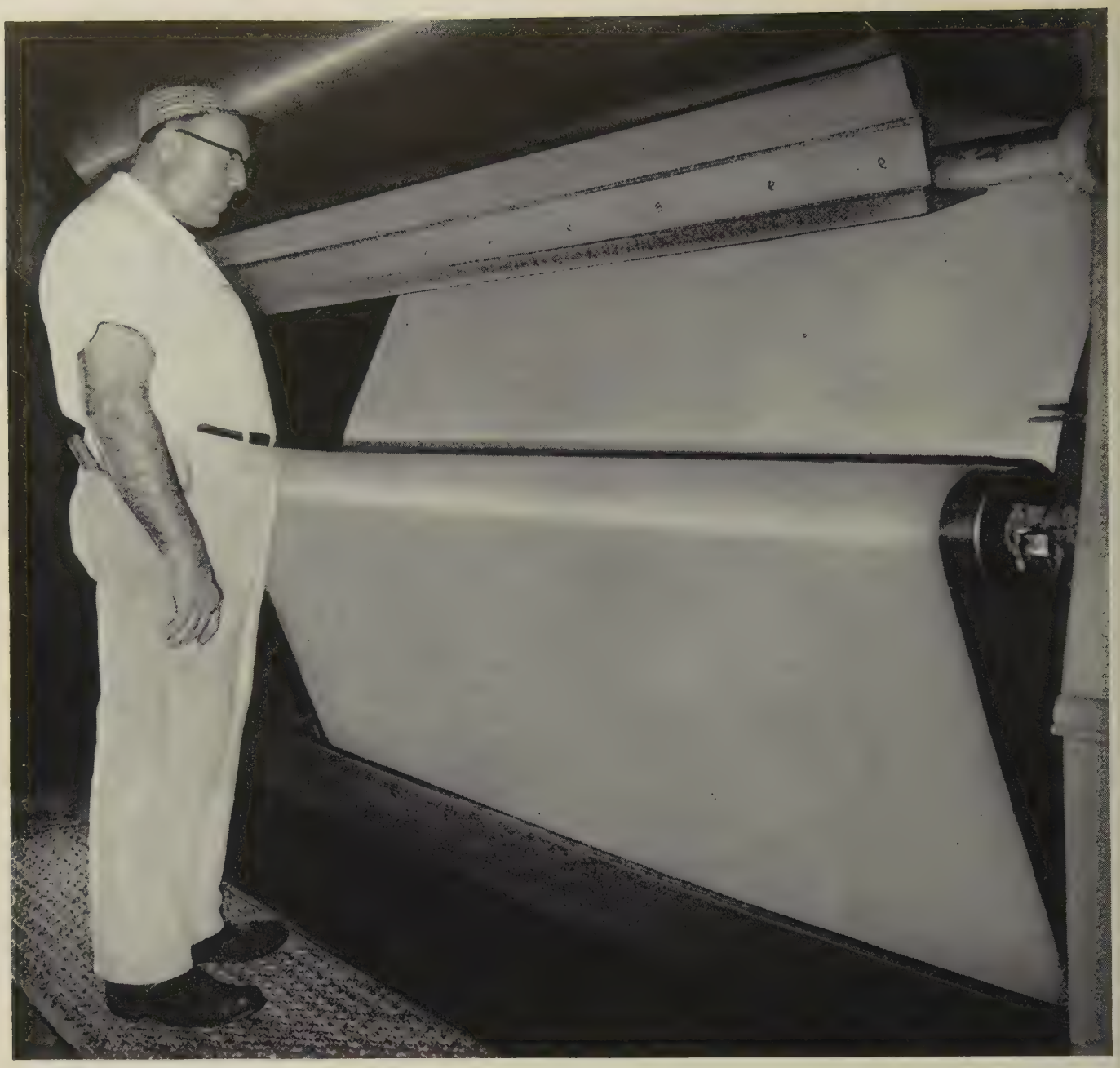
And that's not all, DYLEX K-54 offers *improved pick resistance,* whether in combination with starch or casein. What's more, clay coatings made with DYLEX K-54 have a higher degree of smoothness and excellent mechanical stability.

Want the complete story? Then read our new detailed pamphlet on DYLEX K-54—complete with charts and test data. Write Koppers Company, Inc., Plastics Division, Dept. T-129, Pittsburgh 19, Pennsylvania.

Offices in Principal Cities · In Canada:
Dominion Anilines and Chemicals Ltd., Toronto, Ontario

KOPPERS PLASTICS

KOPPERS

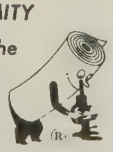


REPAID INVESTMENT—The Albemarle Paper Manufacturing Company of Richmond, Virginia, makes a flame-resistant paper which—because of its chemical coating—has an extremely erosive effect on the average dryer felt. In certain machine positions, for instance, dryer felt life was averaging less than 30 days. In an attempt to find a felt with a greater chemical resistance, Albemarle experimented with a variety of fabrics and blends. None, however, provided the necessary durability until Mount Vernon engineers came up with a specially-designed felt made of 100% Dacron*. The Dacron felt has now been in operation almost continuously in these particular positions for over nine months. Despite its relatively high initial cost, the new felt has cut dryer felt costs per ton of paper to less than one-third of their former costs.

This is another example of how fabrics made by Mount Vernon Mills, Inc. and the industries they serve, are serving America. Mount Vernon engineers and its laboratory facilities are available to help you in the development of any new fabric or in the application of those already available.

PRE-STRETCHED—All Mount Vernon dryer felts are available pre-stretched and pre-shrunk, with or without clipper seams.

UNIFORMITY
Makes The
Big Difference
In Industrial
Fabrics



Mount Vernon Mills, inc.

A LEADER IN INDUSTRIAL TEXTILES

TURNER HALSEY COMPANY
Selling Agents

*Dupont's Trademark

Corrosion can't hide in this fluid end!

You can easily detect corrosive action *before* breakdown with this Goulds Fig. 3715 centrifugal chemical pump.

Turn a few bolts and off comes the casing cover. Then you can inspect the impeller and clean out the insides *without disturbing pipe connections.* A millwright can do the entire job alone.

Mechanical seal or stuffing box is subjected to suction pressure only, reducing the sealing problem to a minimum.

The 3715 handles a wide range of corrosive liquids. It is available from stock in Type CF-8M (316) stainless, Gould-alloy 20, all-iron, aluminum bronze, bronze-fitted or iron with stainless trim. Ten sizes. Temperatures to 350 F. Capacities to 720 GPM, heads to 280 feet.

Write for Bulletin 725.4: Goulds Pumps, Inc., Dept. TA-69, Seneca Falls, N. Y.

GOULDS PUMPS

Hammermill Paper Company's $20,000,000 growth projects constructed by RUST

The present major growth program represents the most progressive period in the 60-year history of Hammermill Paper Company, Erie, Pa. The entire project, under Rust supervision, started several years ago and gained momentum after completion of a new Neutracel® pulp mill in 1955. This mill enables Hammermill to produce fine papers from hardwoods.

New administration building designed by Daniel, Mann, Johnson & Mendenhall, Los Angeles, Calif., and constructed by Rust.

The program, engineered and constructed by Rust, included the following: tripling the size of finishing room, addition to Neutracel building to house digester and pulp-washing equipment, new four-story sulfite pulp mill building, new administration building, new wood room for hardwood pulping operations and new boiler plant addition.

Rust has designed and constructed many 'productive landmarks' serving various industries. Construction specialties have played an important part in the growth of Rust Companies . . . steel plants, chimneys, soil compaction, refractory brickwork, and metallurgical furnaces.

Your inquiry is invited.

THE RUST ENGINEERING COMPANY

- 930 Fort Duquesne Boulevard, Pittsburgh 22, Pa.
- 2316 Fourth Avenue, North, Birmingham 3, Ala.

P-7

BLANCOPHOR®

can make your white papers as bright as this sheet

Blancophor HS and ES optical brighteners in your white papers create a remarkably blue-white, fluorescent finish that adds visibly to the sales appeal of your sheet. The Blancophor brighteners, in liquid or powder form, can be added either *as is* to the pulp, or in solution to the surface. Newly-developed Blancophor ES brands are particularly recommended for beater use at low pH (below 5.0 at the wire), because they are more stable. Use of Solar® tinting colors in the brightened pulp will provide a range of hues extending from greenish-blue to reddish-violet, thus making available a variety of brilliant white tints.

NOTE: This sheet has been whitened with Blancophor ES-73.

Ask for samples and complete technical information at any Antara office.

gaf gdc ANTARA

From Research to Reality

GENERAL DYESTUFF COMPANY • ANTARA CHEMICALS

SALES DIVISIONS OF GENERAL ANILINE & FILM CORPORATION

435 HUDSON STREET • NEW YORK 14, N. Y.

SALES OFFICES: New York • Providence • Philadelphia • Charlotte • Chattanooga • Chicago
Portland, Ore. • San Francisco • Los Angeles. IN CANADA: Chemical Developments of Canada, Ltd., Montreal

Blancophor brighteners and Solar Colors, manufactured by General Aniline & Film Corporation, are sold outside the United States under the trade name of "Tintofen" by distributors all over the world.

B&W JOB-MATCHED WELDING FITTINGS

make piping systems permanent and leakproof

. . . you get positive fit-up to pipe which means welding is easier, faster and more sure

. . . you get dimensional accuracy which means that, with a sound weld, piping is maintenance-free for the life of the system

. . . you get extra long life because you can choose the correct steel for your application

Specify B&W Welding Fittings and Flanges on your next piping job. They're available in a complete range of types and sizes in carbon steel and, of course, the famous B&W CROLOYS. Call your local B&W District Sales Office or any qualified welding fittings distributor. The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pa.

B&W

THE BABCOCK & WILCOX COMPANY

TUBULAR PRODUCTS DIVISION

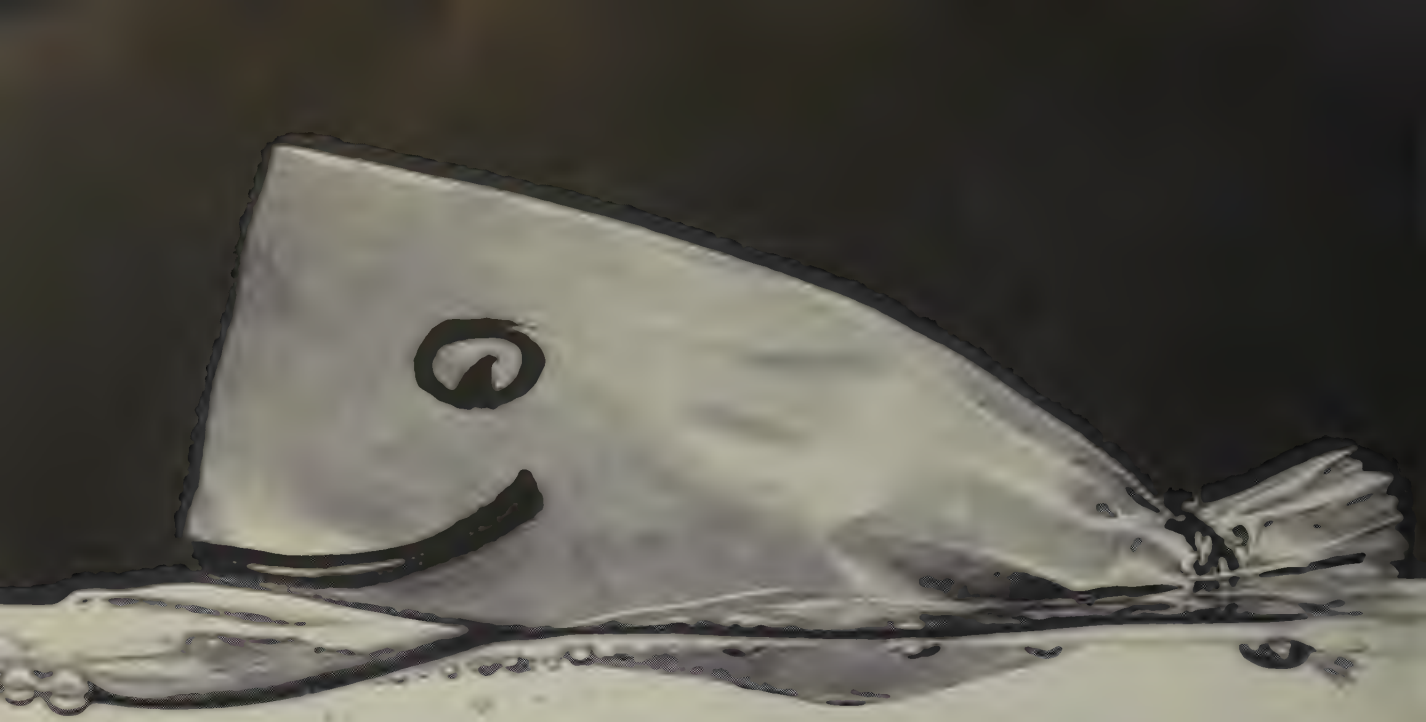
TA 9025-WF3

Seamless and welded tubular products, solid extrusions, seamless welding fittings and forged steel flanges—in carbon, alloy and stainless steels and special metals

Typical of Rice Barton papermaking machines is that built-in extra quality — that gives you all you bargained for, and more — much more.

RICE BARTON CORPORATION
WORCESTER, MASSACHUSETTS U. S. A.
Paper Machinery Builders Since 1837

RICE BARTON



this

paper

was

treated

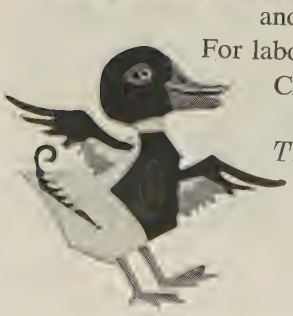
with

SCRIPTITE* 33

A melamine resin supplied as a finely divided dry powder, Scriptite 33 imparts high wet strength to many paper products. Count on Scriptite 33 to increase dry tensile strength and wet rub resistance . . . to improve dry Mullen, wax pick, internal size efficiency, and dry stiffness. Scriptite 33 produces papers with strong fold endurance. For laboratory samples of Scriptite 33 and technical bulletin, write Monsanto Chemical Company, Plastics Division, Room 1159, Springfield 2, Mass.

Monsanto

*SCRIPTITE: Reg. U.S. Pat. Off.



The Monsanto line of paper resins also includes

SCRIPTITE 40 . . . *a urea type wet-strength resin.*

SCRIPTITE 50 . . . *for unsurpassed printability and impr surface characteristics on boxboard.*

SCRIPTITE 52 . . . *in combination with formaldehyde to water resistance to folding boxboard and to jute liner.*

SCRIPTITE 54 . . . *for outstanding water resistance and wet and dry rub resistance.*

Burd & Fletcher Co., Kansas City, Mo., report

"Cities Service Pacemaker 42 Wax gives best results, bar none"...

Burd & Fletcher Company originally started in 1886 as a printing company and then progressed to boxmaking. By 1936 they were producing as many as 2,000,000 boxes a day. Now, Burd & Fletcher is one of the largest paper box manufacturers in the Midwest area, using several hundred tons of paperboard each month.

Burd & Fletcher know that the box they produce can be no better than the wax they use and the coating the box receives. **And after extensive testing, they selected Cities Service Pacemaker 42 for coating their special food boards.**

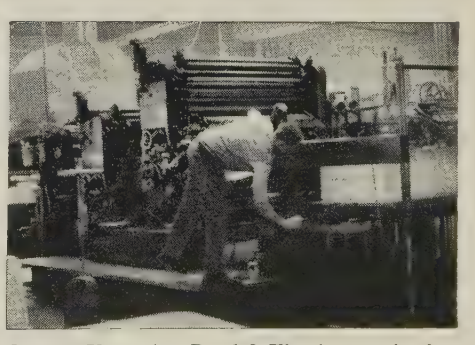
The production department likes Pacemaker 42 for its cleanliness . . . keeps machines running cleaner. Burd & Fletcher also found that Pacemaker 42 produces a smooth gloss . . . better than others tested. Further testing showed Pacemaker 42 gives a full coating, prevents leakers and does not block. **Mr. R. T. Guernsey, Vice President of Burd & Fletcher, especially recommended Cities Service Technical Service Department for their fast, efficient help.**

Contact your nearby Cities Service office for a Wax Representative to give specific recommendations for your operation . . . or for further information, write: Cities Service Oil Company, Sixty Wall Tower, New York 5, N. Y.

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS

Special Cities Service CarTons facilitate easy handling and efficient storage of wax. Local warehousing cuts delivery time and reduces necessary inventories.



Seventy Years Ago Burd & Fletcher used a far smaller press compared to this high-speed giant. When the firm started in 1886, their prime business was printing catalogues.

a real timesaver for
APPA-TAPPI *conventions*

PAPER & PAPER PRODUCTS CONVENTION DAILY
'LIFE BEGINS AT 80' FOR APPA TODAY
Harrison Heads Revamped TAPPI; Fast Growth Spurs Staff Additions
Building Sales to Match New Capacity Seen Meeting Theme
APPA's Community Relations Plan Reported Making Friends for Paper
Cranwood's 'Daily Paper' Forecasts The Paper Picture in A.D. 1977
Market Problems Facing Exporters, Present and Foreseen, Analyzed
SAPI Elects Spicer; Over 1,900 Expected at Today's Luncheon
BIG FARE BILLED FOR
TAPPI to Hear Management Expert Today

• PAPER & PAPER PRODUCTS CONVENTION DAILY

published **February 22, 23, 24, 25, 1960**

• TAPPI REGISTRATION LISTS

published **February 23, 24, 25, 1960**

EVERY MINUTE COUNTS during Paper Week and Paper & Paper Products CONVENTION DAILY puts every second into action for you, your company and your products. It is a valuable low-cost assist in helping you to solve the problem of contacting all of your customers and prospects during the conventions.

No one can be in all places at one time—but Paper & Paper Products CONVENTION DAILY gets around! It is distributed each day before breakfast at the Hotel Waldorf-Astoria, Hotel Commodore and all nearby hotels housing convention delegates. Once the delegates get a copy of Paper & Paper Products CONVENTION DAILY in their hands they never let go —they refer to it constantly. And, for good reasons. The Walden-Mott DAILY tells them quickly where each firm and individual has headquarters, what is going on at the conventions. Briefly stated, their plans for four busy days will be influenced by the information they will receive in the DAILY.

Write or phone for advertising rates. Closing dates for first issue: Advertising Copy, Feb. 1; complete plates, Feb. 8.

PAPER & PAPER PRODUCTS CONVENTION DAILY

One of the Walden-Mott publications for the paper industry

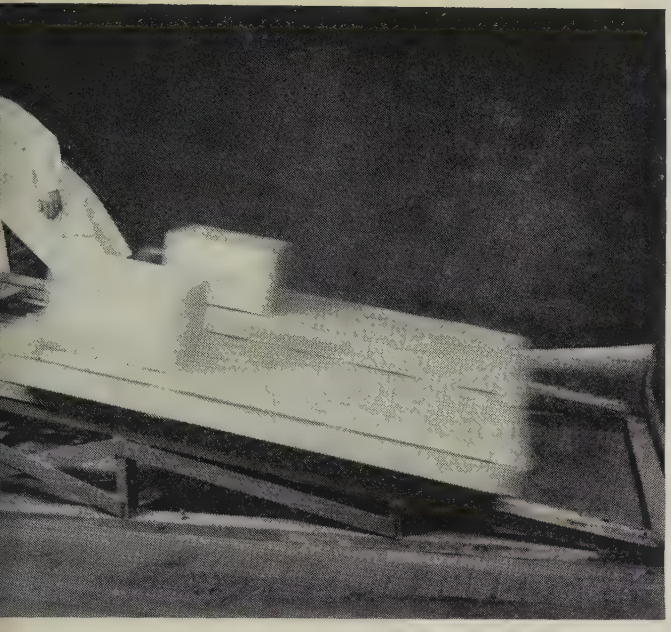
MAIN OFFICE: 466 Kinderkamack Rd., Oradell, N. J.

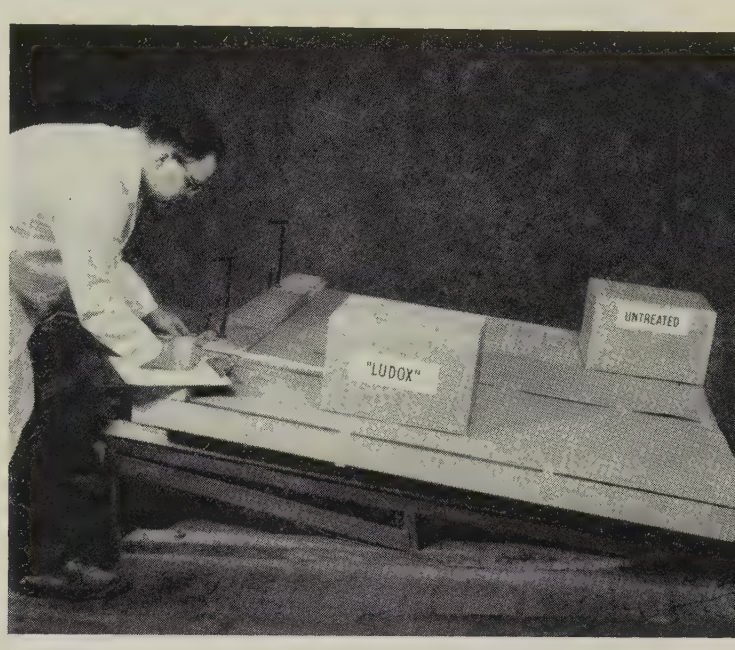
***Western Office:* 6034 N. Cicero Ave., Chicago 30, Ill.**

***Pacific Office:* 140 Geary St., San Francisco 8, Calif.**

Engineering Test Center finds . . .

A coating of Du Pont "Ludox" reduces slippage of corrugated cartons by two-thirds





Here's what happens when plane of Conbur inclined impact tester is released and strikes barrier at six miles per hour. Impact causes untreated carton to slide full length of plane. Other carton, treated with "Ludox" colloidal silica, moves only about one-third as far.

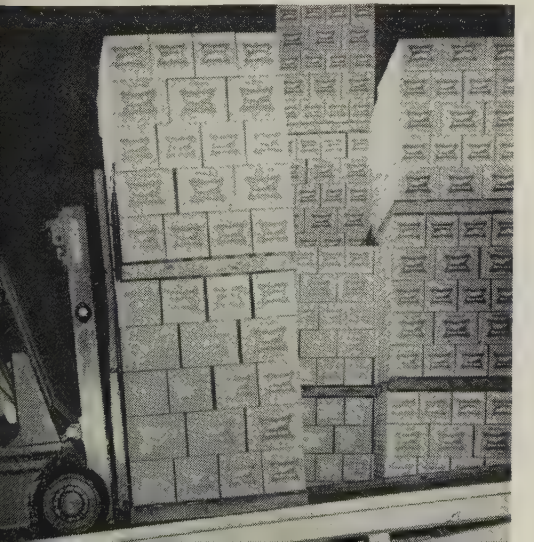
A sudden stop or start can send a stack of cartons sliding so easily that when a package is damaged during shipping, impact is the cause three times out of four. In such cases, the difference between costly damage and safe shipment can be a remarkably simple thing—an invisible coating of Du Pont "Ludox" colloidal silica.

To find out precisely what advantages "Ludox" offers package users, Du Pont's Engineering Test Center recently ran a series of studies using a Conbur inclined impact tester. Corrugated cartons coated top and bottom with submicroscopic particles of "Ludox" slid only about one-third as far as untreated ones.

Users of treated cartons say they are much more stable during in-plant handling as well, minimizing threat of injury to employees. What's more, they resist soiling and offer a sharper printing surface.

Coatings of "Ludox" can be applied to paper or to finished packages by either mills or converters. For names of suppliers of treated cartons and more information about "Ludox", fill out the coupon below.

Miller Brewing Co., Milwaukee, reports that antiskid coating of "Ludox" reduces product damage caused by falling boxes and makes palletizing safer for employees.



DU PONT
REG U.S. PAT. OFF

LUDOX®
COLLOIDAL SILICA

BETTER THINGS FOR BETTER LIVING...*THROUGH CHEMISTRY*

E. I. DU PONT DE NEMOURS & CO. (INC.)
INDUSTRIAL AND BIOCHEMICALS DEPT., RM. N-2533T
WILMINGTON 98, DELAWARE

Please send me more information about ( ) antislip coatings of "Ludox".
Send me ( ) names of companies supplying treated paper products.

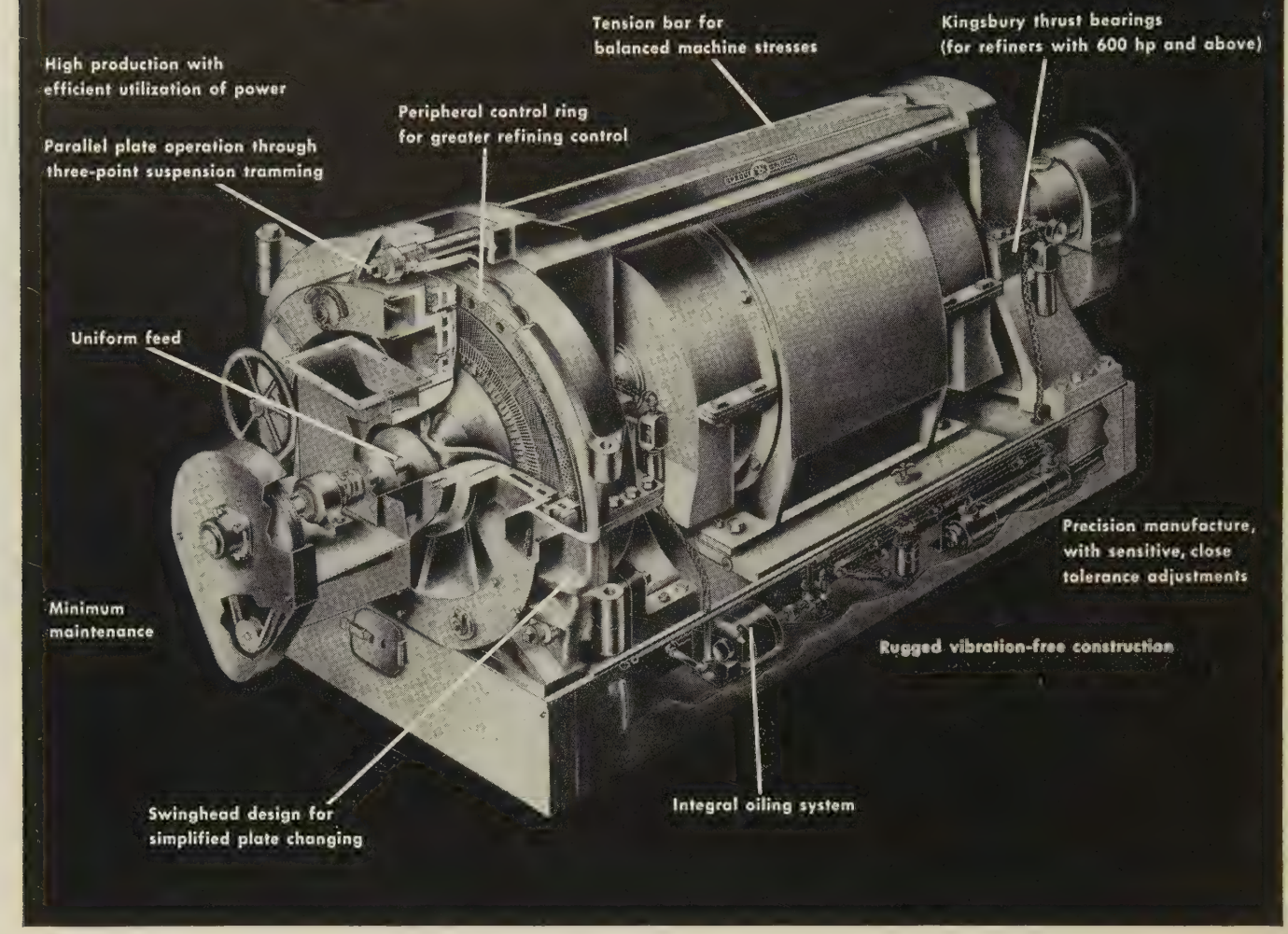
*Name*_____ *Title*_____

*Firm*_____

*Address*_____

*City*_____ *State*_____

11 POINTS OF SUPERIORITY


Tension bar for balanced machine stresses
Kingsbury thrust bearings (for refiners with 600 hp and above)
High production with efficient utilization of power
Peripheral control ring for greater refining control
Parallel plate operation through three-point suspension tramming
Uniform feed
Precision manufacture, with sensitive, close tolerance adjustments
Minimum maintenance
Rugged vibration-free construction
Swinghead design for simplified plate changing
Integral oiling system

THE WORLD-FAMOUS 36-2 "SPROUT"

single disc precision pulp refiner

The 36-2 Sprout refiner is the most efficient disc refiner in quantity of output and in quality of refined pulp per horsepower input. It is preferred throughout the industry for every pulping application where rubbing and brushing action, without cutting, is required. Sprout-Waldron units lead the field in the refining of semichemical pulp, cold caustic pulp, screen rejects, wastepaper stock; brown stock and hot stock refining of high yield kraft pulp; refining of bagasse, flax and straw pulping; as well as preparation of insulation and hardboard fiber. For the latest details on the 36-2 Sprout, request Bulletin 96-B.

SPROUT, WALDRON & CO., INC.

MUNCY, PENNSYLVANIA, U. S. A.

SINCE 1866 REFINERS • DIGESTERS • CONVEYORS • FEEDERS • SCREENS • MIXERS • DRAINERS • FIBER PRESSES • STOCK PROPORTIONERS

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EC&M *Fuseless* AIR-BREAK STARTER

GIVES Certified

100/150 MVA FAULT PROTECTION

NO SINGLE PHASING FROM BLOWN FUSES!

NO COSTLY REPLACEMENT FUSES TO STOCK!

✔ Gang-operated Disconnect Switches Grounded for Safety in Open Position. Mechanically Interlocked with Contactor... Never Open Under Load

✔ No Fuses. Bus Bars Throughout

✔ 3-way Door Interlock. On, Off and Open—with Positive Interlocking between Door, Disconnect and Contactor for Maximum Personnel Protection

✔ Heavy-duty DC Operating Magnet. No Chatter—No Hum

FRONT ACCESSIBLE WITHOUT ROLL-OUT!

Phase barrier and arc-chutes slide out. All starter parts exposed and accessible for easy inspection and maintenance

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Further information available from the Paper and Corrugating Department of Stein Hall & Co., Inc.
STEIN SH HALL
285 MADISON AVENUE NEW YORK 17, N. Y.
ESTABLISHED 1866

New Nalco Coagulant makes Larger, Heavier Floc . . . Faster

Radically different Nalcolyte 110 used with Conventional Chemicals to Cut Costs, Speed Action in Water Clarification

Photo taken in Nalco Laboratories 7 seconds after agitation stopped: *Left*, Control sample of untreated turbid water; *center*, same water, treated with 50 ppm alum; *right*, same water, treated with 20 ppm alum, 1 ppm Nalcolyte 110. Note that large, dense floc is settling out much more rapidly than center alum-treated sample.

Nalcolyte 110 is a new, non-ionic high polymer flocculant of very high molecular weight—over 1,000,000. It is used in extremely small dosages with conventional coagulants (such as sodium aluminate, alum, ferric sulfate) to increase size, density and uniformity of floc.

Less Chemical; Greater Capacity

Action of Nalcolyte 110 in creating heavier, larger, faster-settling floc not only permits greater throughput rates without floc carryover to processing equipment, but also cuts the total chemical requirements at a resultant cost saving.

In the example illustrated above, only 40% as much alum is required when Nalcolyte 110 is used.

May be Used in Potable Waters

Approved by the U. S. Public Health Service Technical Advisory Committee for use in treatment of public water supplies, Nalcolyte 110 gives water works the opportunity to get appreciably greater capacity from existing clarification equipment—at lower treating cost.

High Suspended Solids No Problem

Waters containing high suspended solids respond quickly to Nalcolyte 110 coagulating action . . . frequently without other coagulant chemicals.

Typical high suspended solids waters which can be treated with speed and economy with Nalcolyte 110 are paper mill white water systems, industrial waste waters, mineral slurries and blast furnace gas wash water slurries.

Nalcolyte 110 Easy to Handle

Nalcolyte 110 is a coarse, white, free-flowing powder of non-toxic character. It is fed in dilute water solutions with standard liquid proportioning pumps or feeders. Stock solutions are prepared at concentrations up to 20%. Packaging is in convenient 25-lb. bags.

Data Available Promptly

Full information on Nalcolyte 110 for your coagulant use is ready to be sent upon your request. Write today, or call your Nalco Representative.

National Aluminate Corporation is now

NALCO CHEMICAL COMPANY

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Subsidiaries in England, Italy, Mexico, Spain, Venezuela and West Germany
In Canada—Alchem Limited, Burlington, Ontario

Nalco® . . . Serving Industry through Practical Applied Science

Nalco CHEMICALS

FLUIDICS

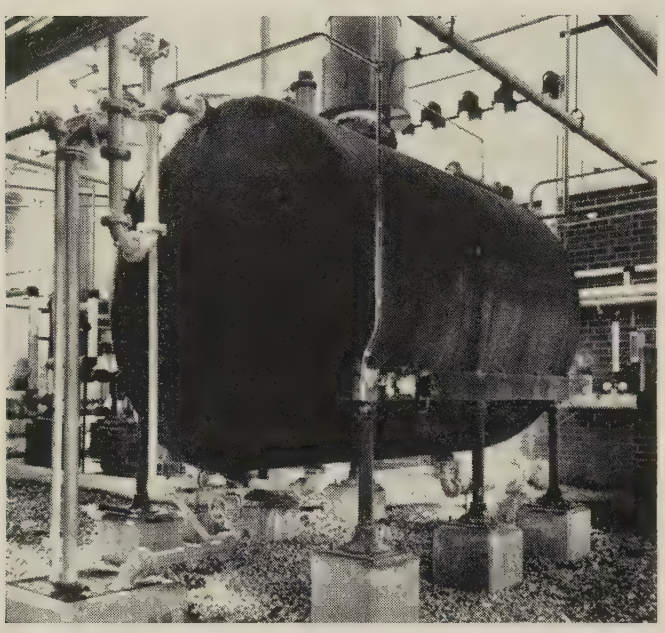
is a new PFAUDLER PERMUTIT program that provides a modern, imaginative approach for handling and processing more profitably the liquids and gases involved in such operations as:

corrosioneering
water treatment
waste treatment

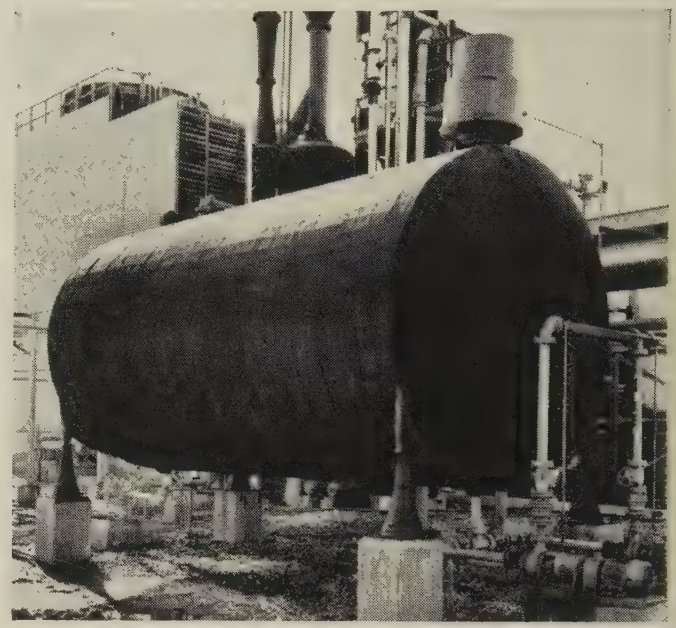
flow rate control
heat transfer
fluid analysis

pumping
reactions
agitation
blending

metering
valving
piping
storing



Waste liquors, highly corrosive, are accumulated in Glasteel at Marathon Southern in this 5000-gallon Glasteel Chemstor tank.



15,000-gallon storage tank of Glasteel construction keeps chlorine dioxide safe and pure until it's ready for use.

FLUIDICS AT WORK

How Marathon Southern uses Glasteel in chlorine dioxide generation

One of the major factors to consider in setting up a chlorine dioxide plant is the corrosiveness of chlorine dioxide itself and of the chemicals used to generate it.

Depending on the process you use, you run up against sodium chlorate, sulfuric acid, methanol, and sulfur dioxide.

One construction material is completely resistant to all and any combination of these chemicals . . . Pfaudler Glasteel.

That's why you'll find Glasteel equipment so much in evidence at Marathon Southern's new chlorine dioxide plant. This single material from one fabricator solves *all* the corrosion problems encountered.

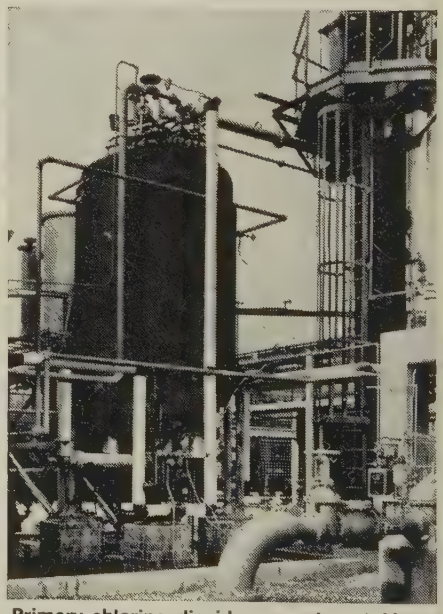
More than 35 pulp mills are now using Glasteel equipment for everything from generators to storage tanks and towers, from pumps and pipes to fittings and valves.

If you're considering a new chlorine dioxide plant or expanding or revamping an old one, take advantage of Glasteel, the modern material of construction for ClO_2 equipment, provided by our FLUIDICS program. You can get a complete analysis covering original prices, maintenance costs, and length of equipment life simply by contacting your Pfaudler representative.

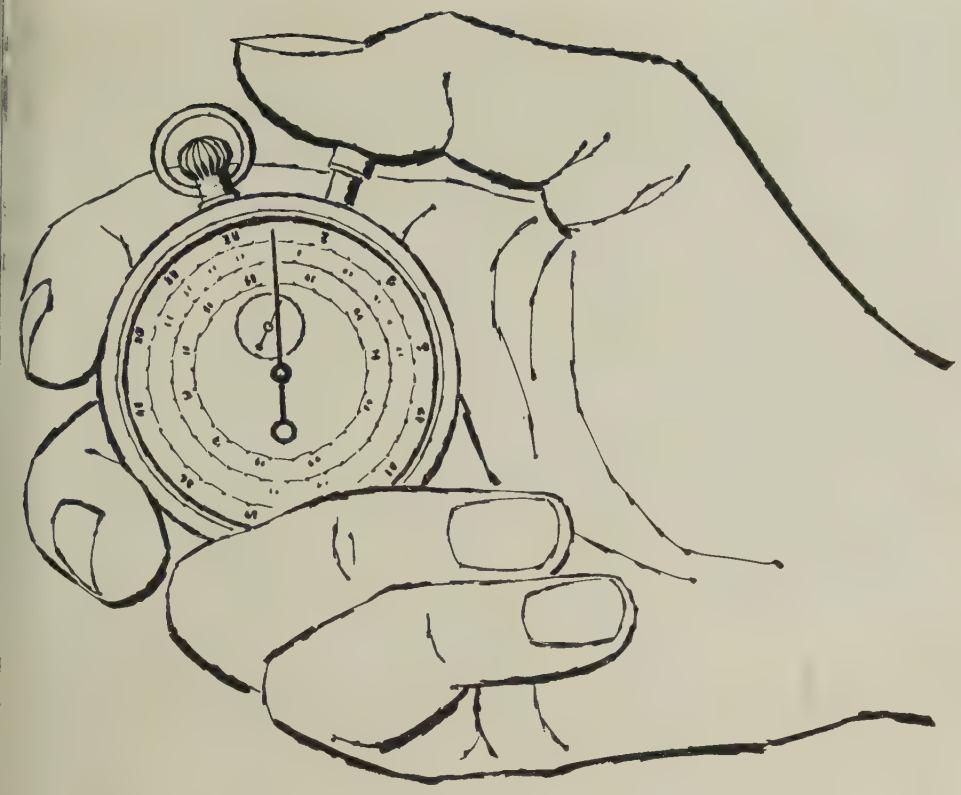
Or write direct to our Pfaudler Division, Department TA129, Rochester 3, New York.

PFAUDLER PERMUTIT INC.

Specialists in FLUIDICS . . . the science of fluid processes



Primary chlorine dioxide generator at Marathon Southern. Five-ton-per-day capacity. Like most of the chlorine dioxide equipment at this installation, it's corrosion resistant Glasteel.



Time impregnation with a stopwatch?

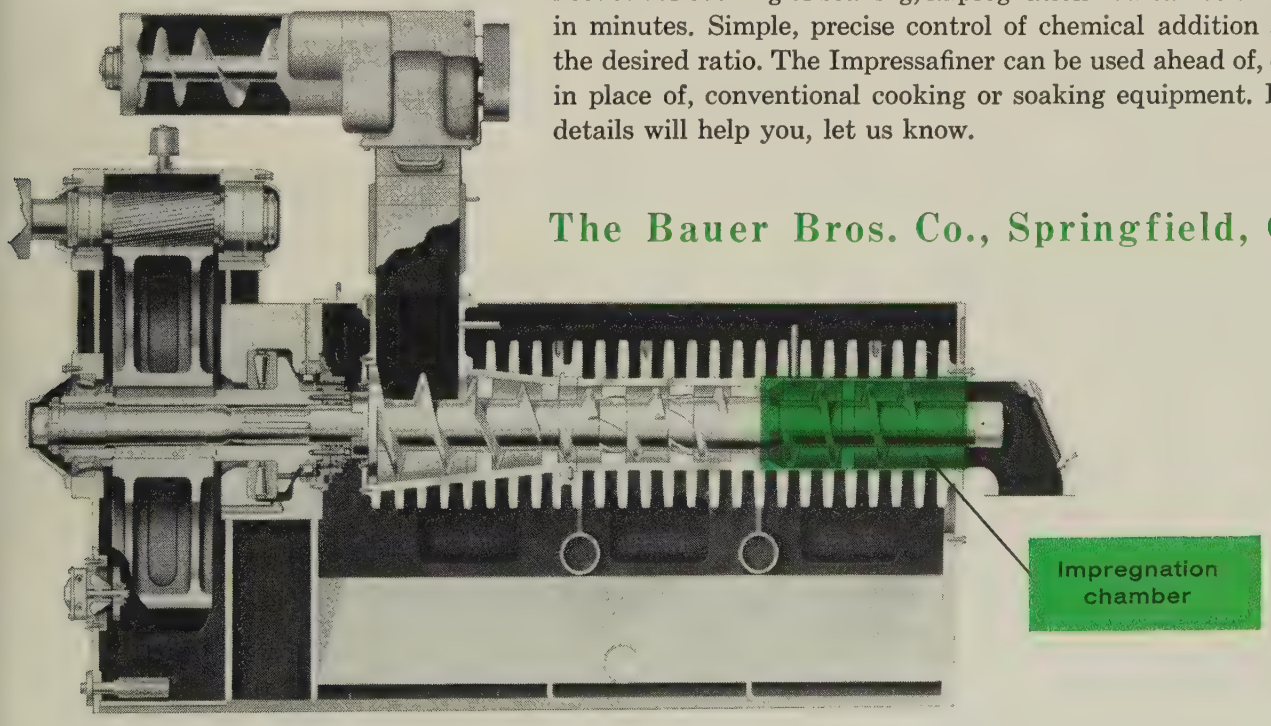
Here's the newest concept in continuous pressurized impregnation

Bauer
NO. 567
IMPRESSAFINER
(Patents and trademark registrations applied for.)

Are you interested in thorough, uniform impregnation of chips . . . at a fraction of the time usually required? It's now possible, with Bauer's new No. 567 Impressafiner. Based on basic Bauer patents for high pressure screw press equipment, the Impressafiner puts newly applied engineering principles to work for you.

In certain processes, where an hour or more was normally needed for cooking or soaking, impregnation now can be completed in minutes. Simple, precise control of chemical addition assures the desired ratio. The Impressafiner can be used ahead of, or even in place of, conventional cooking or soaking equipment. If more details will help you, let us know.

The Bauer Bros. Co., Springfield, Ohio



New Trona® tank car fleet speeds sodium chlorate service

Custom-built for American Potash & Chemical Corporation, a new and thoroughly modern fleet of tank cars is being added to better serve Sodium Chlorate users from coast-to-coast.

Designed to carry bulk $NaClO_3$, the cars are being equipped with a specially engineered system for unloading that saves both manpower *and* hours. A protective lining maintains product purity. The new design also stresses easy accessibility, increased safety and convenience.

Watch for these new tank cars—reflecting the quality of Trona chemicals and service—modern to the minute.

American Potash & Chemical Corporation

3000 WEST SIXTH STREET, LOS ANGELES 54, CALIFORNIA
99 Park Avenue, New York 16, New York
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TRONA®

ALBACEL & ASTRACEL

CHLORINE DIOXIDE BLEACHED SOFTWOOD SULPHATE

CHLORINE DIOXIDE BLEACHED HARDWOOD SULPHATE

Balanced Paper-Grade Pulps Created by Papermakers for Papermakers

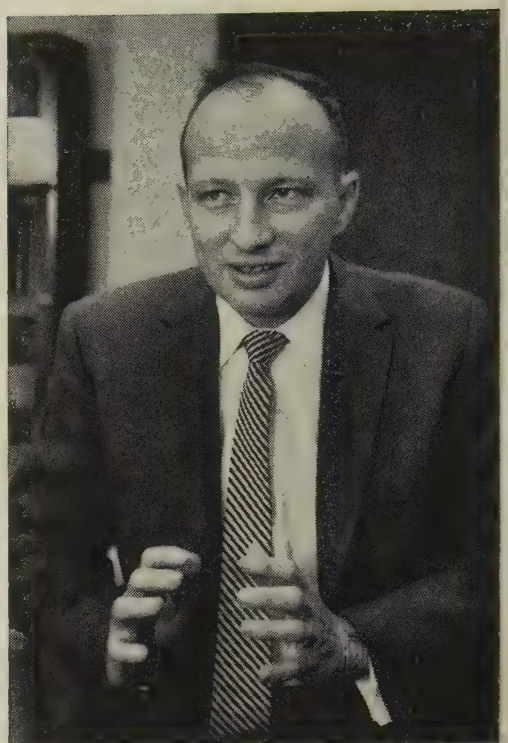
Throughout the free world, papermakers use and like Riegel's Albacel and Astracel . . . paper-grade pulps that provide the right balance of all important qualities . . . brightness, cleanliness, strength, formability and proper beating characteristics.

RIEGEL PAPER CORPORATION

260 MADISON AVENUE, NEW YORK 16, N. Y.

One in a series of interviews with the men who are "Virginia"

"Bleaching groundwood pulp with hydrosulfites can be done easily—with minimum capital investment—for less than $6 per pulp ton, including chemicals and steam for heating"



Robert Barton, a "Virginia" technical representative

Simplicity of operation, low cost, high pulp brightness—these factors have attracted many groundwood pulp processors to the use of either sodium or zinc hydrosulfite as their principal bleach agent.

The advantages of hydrosulfite bleaching are discussed by Robert Barton, a technical representative of Virginia Smelting Company.

Q How does the cost of bleaching with hydrosulfite compare with the cost of oxidizing bleaches?

A Extremely well. The cost of using zinc or sodium hydro usually runs less than one-half that of the oxidizing bleaches, and with equally good results.

Q Just what is the brightness gain using hydro?

A That question has to be qualified somewhat, I think. You see there are factors that have to be considered in bleaching groundwood pulp with hydro —the *p*H of the stock, temperature, reaction time, iron content of the pulp and of the process water. But with reasonably good conditions, single-stage bleaching with hydro will result in about 10 or 12 brightness points gained.

Q Does installation of equipment present any problem?

A Not at all. Most manufacturers who have gone to the hydro bleaching process are well pleased with the simplicity of the installation. And at the low cost, I might add. Generally they can use existing chests and pumps in their plants —adding necessary piping. Not much more is needed.

Q Do the hydrosulfites offer any advantages to a manufacturer now using peroxide for his bleach?

A Very definitely. In our laboratories at "Virginia" we have helped develop the 2-stage bleach for groundwood pulp that gives an absolute maximum brightness—at a cost that cannot be touched by any other method.

Q How does this 2-stage bleaching work?

A Well, for brightness gains up to 12 points, of course, the single-stage hydrosulfite bleach is the most economical. But for gains from 12 to 20 points, we recommend a 2-stage bleach. The first stage is a peroxide bleach. We follow that with a sulfur dioxide treatment to remove any residual peroxide in the slurry. This is followed by a hydro bleach. We will be happy to furnish all the data to anyone interested in this process.

Q Does "Virginia" offer technical assistance to any manufacturer interested in either the single-stage or 2-stage bleach process?

A A great deal. Our experience in this field is long and extensive, and available to anyone interested. For preliminary bleaching studies, we maintain a complete pulp laboratory at our plant. To solve certain types of problems, we obtain pulp samples, make laboratory bleaches, study the brightness gains along with any contributory factors, and make a complete report to the manufacturer. Along with the report go our recommendations—and of course our laboratory men are quite impartial in their findings. If the manufacturer has a process involving problems that make hydro impractical for any reason, we will tell him so quite frankly. But this occurs very infrequently. We welcome inquiries from any manufacturer interested in exploring the possibilities of hydrosulfites in pulp bleaching.

• • •

FOR MORE DATA ON HYDROSULFITES write to us on your company letterhead describing your present bleaching process, giving full details wherever necessary. We will send you pertinent technical bulletins from the extensive "Virginia" library of literature on pulp bleaching. If you prefer, we will have a "Virginia" man call on you.

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II — Shipping Molten Sulphur
III — Handling and Storage of Molten Sulphur
IV — Analysis of Sulphur
Appendix — Physico-Chemical Properties of Sulphur

Old hands, accustomed for years to handling Solid Sulphur, will need little advice, if any...unless Molten Sulphur is to be in the picture for the first time. In this case, our experience with and knowledge of Molten Sulphur may be helpful.

But new plants entering the Sulphur-consuming picture for the first time should find our service of considerable help regardless of the kind of Sulphur used. One facet of this service consists of a well-documented and well-illustrated 5 section Manual covering all phases of the handling, storage and use of Sulphur, both solid and molten, plus useful information on sampling, analyzing, and broad properties of Sulphur.

As a preliminary to any service in person you may require—and which we shall be glad to provide—would you like to have a copy of this Manual? Please write us on your company's letterhead and address your request to our Sales Department.

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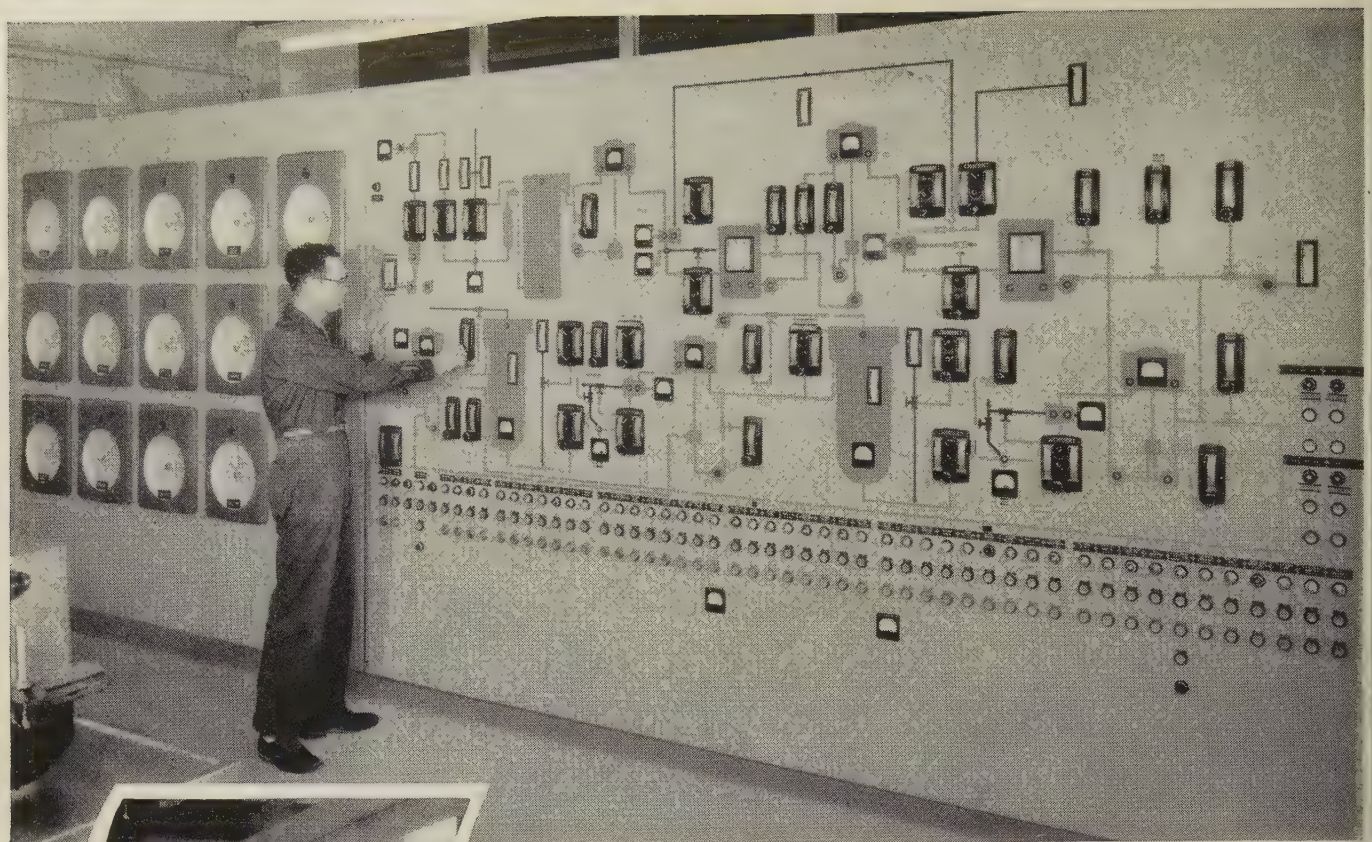

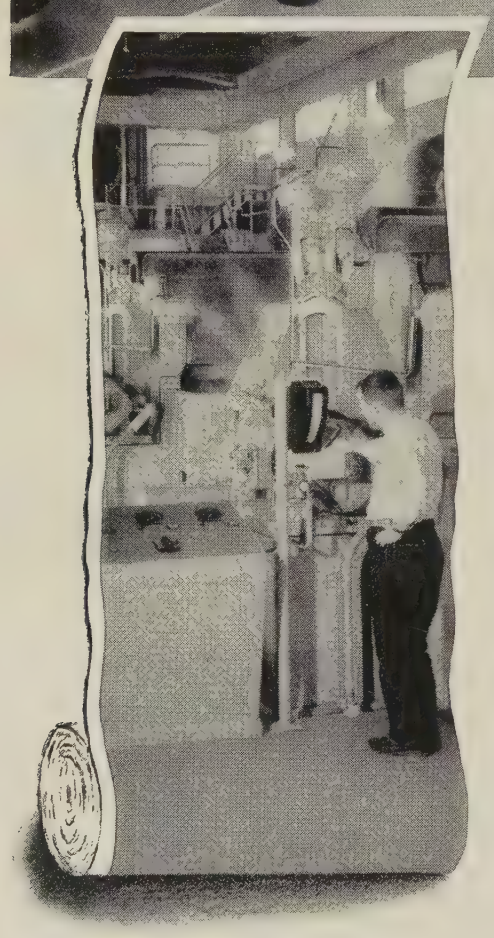

Photos courtesy Marathon Southern Corporation

Bailey controls Marathon's five-stage bleach plant!

Marathon Southern's five-stage bleach plant at Naheola, Ala., is one of the most completely instrumented in southern U.S.A.

Rigid quality control—automatic and foolproof—keeps production going at top speed with unvarying excellence in the finished product.

The panel board in the central control room (above) was built and instrumented by Bailey. Note how it is divided into two sections. The 15 Bailey Recorders in the recorder section provide continuous circular chart records. The functional graphic panel on its right provides a complete visual picture of the entire process. Important control variables such as stock consistency, stock flow, bleach liquor flows, stock temperatures, etc., can be watched and instantly corrected, either automatically or manually.

At the same station, the operator can supply consistency-controlled stock (from any of four storage towers) to any of the semi-bleach, pine bleach, or gum bleach pulp chests on a ratioed flow, automatically controlled basis.

Each of the five vat bleach washers is equipped with automatic level control (as shown at left).

This is but one example of how Bailey is helping pulp and paper processors to greater degrees of automation, efficiency, and quality control. Let your Bailey Engineer suggest applications to fit your operation. Or write for specific control systems information for your entire plant operation.

P149-1

PULP AND PAPER DIVISION

BAILEY METER COMPANY

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BAILEY METERS

THREE NEW "PONTAMINE"* DIRECT DYES GIVE IMPORTANT PRODUCTION ECONOMIES

The "Pontamine" family of direct dyes now offers you a unique fast brown, a new bond yellow, and a new bond blue that can be used to produce highly attractive colors with good (or better) lightfastness. Even more important, these new dyes have characteristics which can lead to worthwhile production economies. Whether your mill makes sized papers or tissues, kraft or board stock, the chances are that one of the dyes will save you money.

"Pontamine" Fast Brown NP

Most direct brown dyes have tended to produce "browns" or "tans" of too much brightness. As a result, it has been necessary to use shading colors. "Pontamine" Fast Brown NP, however, gives reddish, true-brown shades that usually need *no shading*.

You'll find Fast Brown NP an economical way to color wrapping or blotting grades, board stock, and other grades of paper. You can use it with good results in either straight or combination shades. It handles easily too —no dusting, practically no foaming.

"Pontamine" Bond Yellow CS

An extremely versatile dye, "Pontamine" Bond Yellow CS permits low-cost coloring of most paper grades: bond, writing, mimeograph, duplicator, and envelope stock. Unsized papers such as tissues can also be economically dyed; alum is not necessary.

The "yellows" produced by this dye are attractive and brilliant. Its non-twosided properties are good, especially when fillers such as titanium dioxide or clay are used. Neither is the pH critical. "Pontamine" Bond Yellow CS has good affinity for the fiber even at moderately high pH values. However, the dye can be readily bleached out by using a hypochlorite bleach.

"Pontamine" Bond Blue B

Attractive bright blue shades and non-twosided characteristics make this dye an excellent candidate for bond and cover papers. Its lightfastness is very good . . . and it bleaches easily to permit re-use of trim waste.

Compared to the usual bond blues, "Pontamine" Bond Blue B is more economical to use. Another advantage: it reaches full color value with only a short mixing time. Still another: it is more resistant to fading when exposed to gas fumes in printing plants.

This direct dye also gives attractive "greens" when shaded with Du Pont yellow dyes. As you prefer, you can produce green shades with good lightfastness or with good non-twosidedness and satisfactory lightfastness at lower cost. "Pontamine" Bond Blue B can also be used for tissues since its retention is quite good on papers made without size, alum or both.

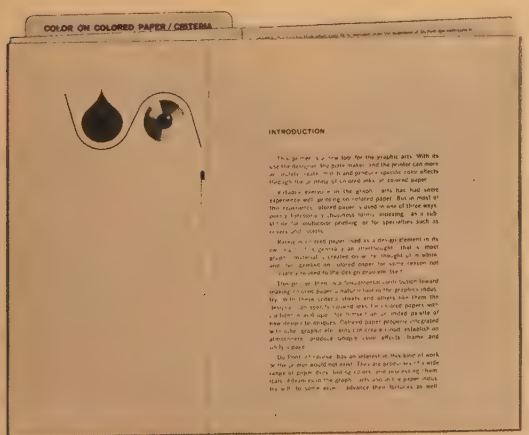
Investigate these new "Pontamine" dyes soon. For more details, or application suggestions, simply get in touch with the nearest Du Pont district office.

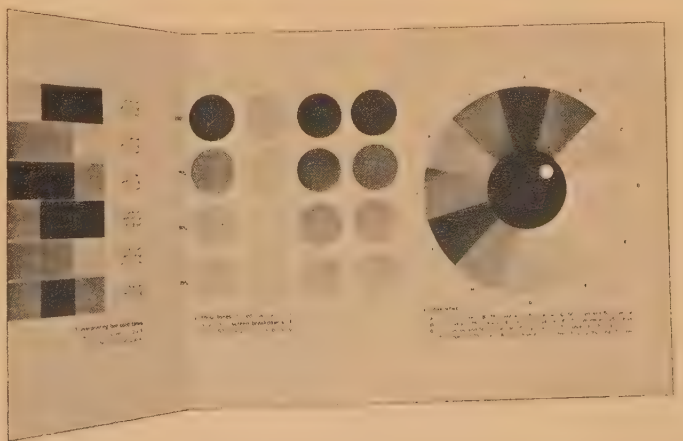
news from Du Pont

LATEST DOINGS OF THE DU PONT COLOR COUNCIL

What does it take to increase the acceptance and use of colored paper? That's the assignment of Du Pont's Color Council—a group of people experienced in art, color, and printing. This year, as one of their projects, the Council has developed a primer—"Color on Colored Paper"—a collection of seven sheets of offset paper dyed as close as possible to spectrally pure, deep shades of the primary and secondary colors plus fluorescent. On these are printed the fundamental elements of most modern printing: type reverse, halftones, duotones, and pure, screened and overlaid tint blocks. This primer demonstrates a technique by which paper manufacturers and merchants can assist graphic designers and printers utilize their colored papers more effectively.

For further information on the primer and other Color Council projects write: Color Council, Nemours 2420-A, Du Pont Company, Wilmington 98, Delaware.





DU PONT SURVEY SHOWS PRINTERS AND ARTISTS ARE THE KEY TO GREATER SALES OF COLORED PAPER

A Du Pont survey on colored paper offers strong evidence that more color stock can be sold through aggressive selling and promotion programs. Printers already believe that there is a definite trend to color printing, and that it means more profit for them. Second, most commercial artists and advertising agency art directors feel that colored paper offers them important advantages in design.

But the undertaking of promotions is only one key to success; another is in reaching the primary specifying influences. The survey provides some convincing answers on this score.

Printers Could Have Great Influence

On the average, printers do the planning and layout of 45% of their printing jobs. They also are in a position to recommend colored paper in many other cases. However, eight of ten suggest colored paper in only about 11% of all jobs handled. If printers are encouraged to take the initiative more often, there is little doubt that they can become one of the most important influences in the use of color stock.

Artists Are a Big Influence

When advertising agencies design printed pieces, they specify the paper for all but 7% of their jobs. Within the agency, the art director and layo man say they usually decide wheth colored paper or white paper will used. This decision, the survey veals, is extremely important becau most printed material is produced the same paper used in layout. All e dence points up the importance of personnel, and the fact that they mu be included in any selling or prom tional programs.

Ways in which mills can effectiv promote colored paper will be d cussed in future articles. Be sure look for them.

HIGHLIGHTS OF COLORED PAPER SURVEY

How Often Printers Say They Suggest Color Stock

% of Printers Who Do	% of All Jobs
34%	5% or less
25%	6% to 10%
9%	11% to 15%
8%	16% to 20%
8%	21% to 25%
14%	26% to 50%
Only 2%	Over 50%

Specifying Influences for Agency Jobs

(In Artists' Opinion)

Who Specifies	% of Jobs
Art director	67%
Layout man	12%
Account executive	6%
Printer	1%
Client	14%

news from Du Pont

ADDITION OF FOA-2 TO HEAVY FUEL OILS SAVES MONEY 3 WAYS

Burner nozzle after two days of operation with solvent-type additive

Burner nozzle after nine days of operation with Du Pont FOA-2

Mill heating and power plants can now use heavy fuel oils with greater over-all economy, simply by adding Fuel Oil Additive No. 2 to storage tanks. In one case alone, $20 of this fuel oil additive has saved a mechanical cleaning bill of $800. Here's how FOA-2 can save you money, too.

First, it helps prevent sludging in tanks, plugging of strainers and deposits on burners. Second, FOA-2 cleans up fouled systems so effectively that you can often eliminate expensive mechanical cleaning and costly down-time. Third, this new kind of additive should improve your over-all operating efficiency.

Request further information about FOA-2 today from a Du Pont Sales Representative, or by writing direct to us on your company letterhead.

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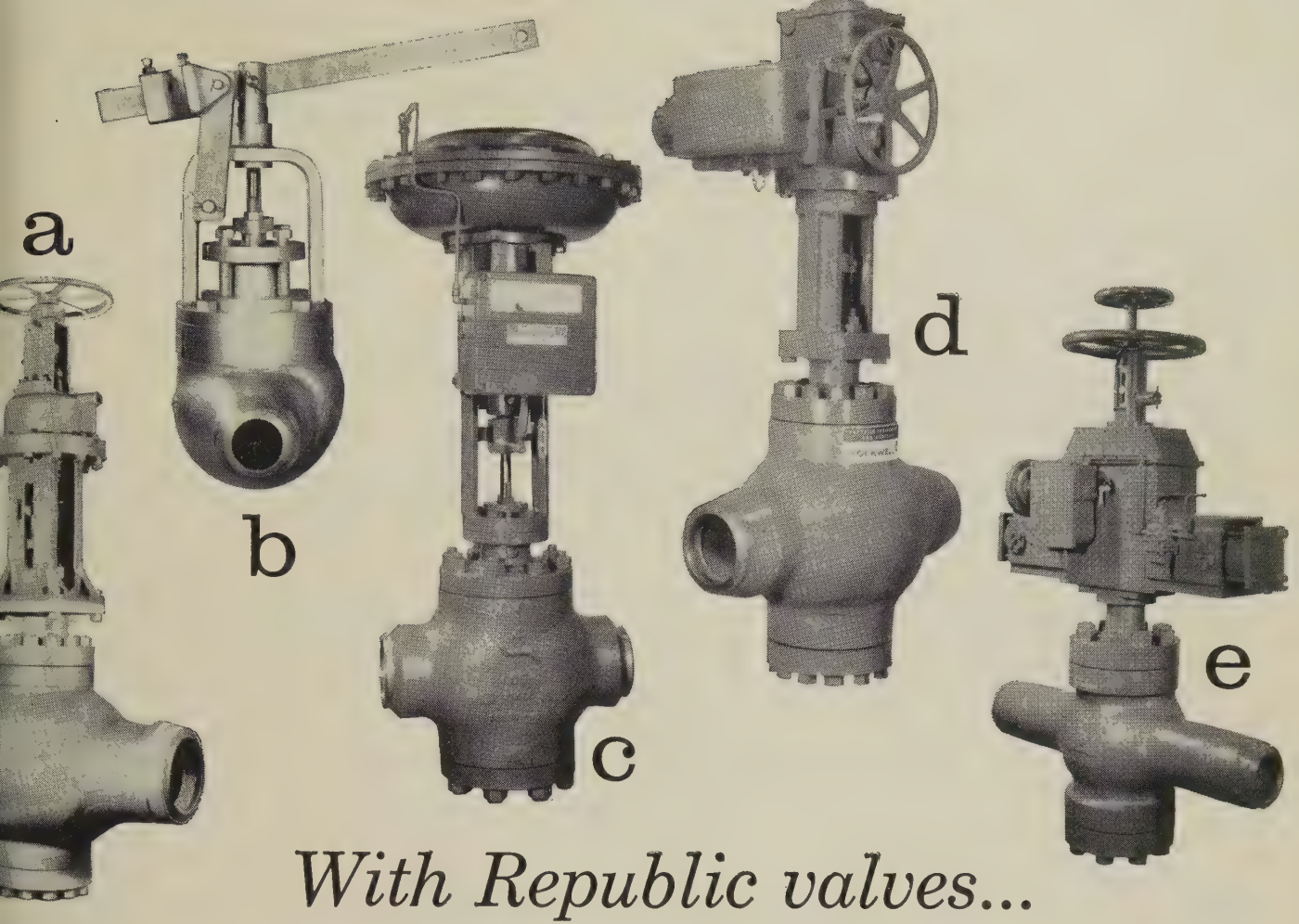

With Republic valves...

You get longer life, less maintenance

For over 35 years Republic valve developments have paced the changing demands for more sturdy valves by the most progressive utilities and industries. For such services as pump recirculation control, feedwater regulation, steam pressure reducing and high pressure water control, Republic valves have established a reputation for durability, long life and trouble-free performance.

Superior valve design—Republic research into the causes of valve noise and vibration, and also the wear resisting and galling properties of materials has resulted in a modern line of Republic valves of advanced design. Republic valve contours are designed to produce not only the desired regulating characteristics but also to reduce erosion damage and noise as well. Extra large guide bushings, extra deep stuffing boxes, solid plug inner valve construction, plus precise manufacture and long-life materials make Republic regulating valves perform better, last longer, with less maintenance.

Wide selection of valves and features—Rockwell-built Republic regulating valves shown on this page are representative of the complete Republic line:

a. **Cylinder operated valve**
b. **Lever operated valve**
c. **Diaphragm operated valve**
d. **Motor operated valve**
e. **Toggle head operated valve**
f. **Diaphragm operated angle valve**

And, for many special applications, such Republic accessories as pneumatic and electric valve positioners for hysteresis-free control, and a complete line of controllers are available.

Whatever your regulating valve problem, let Republic engineers put their years of application experience to work for you. For additional information, see your Republic representative, or write to Republic Flow Meters Company, 2240 Diversey Parkway, Chicago 47, Illinois.

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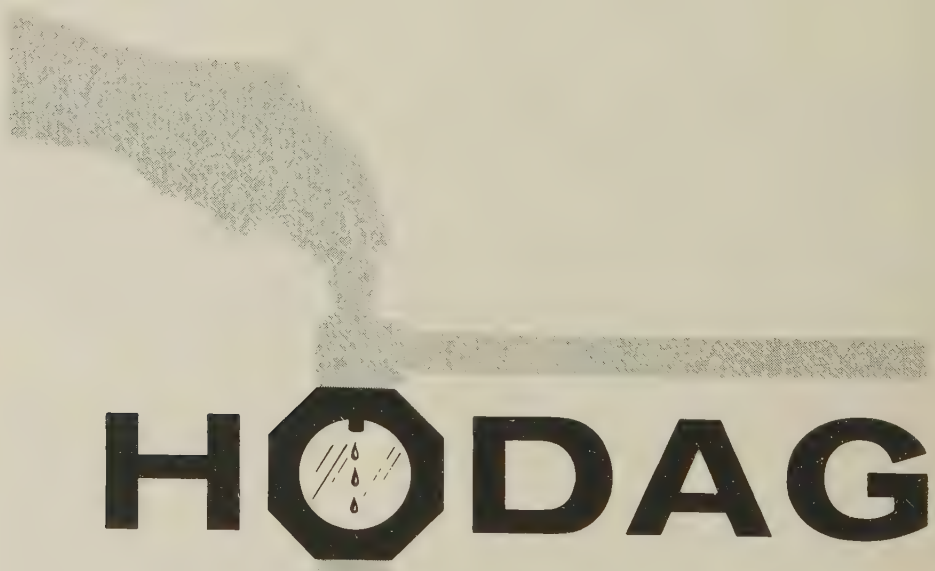

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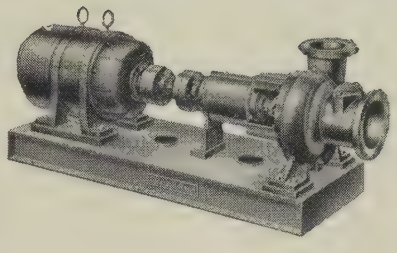
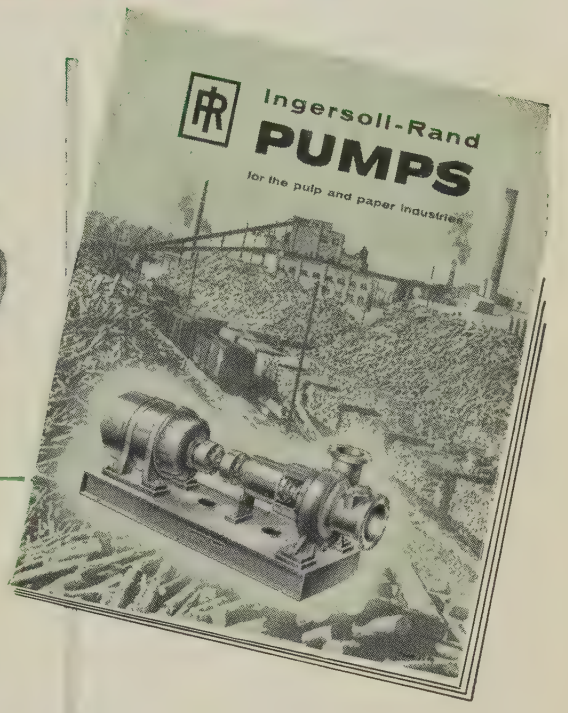
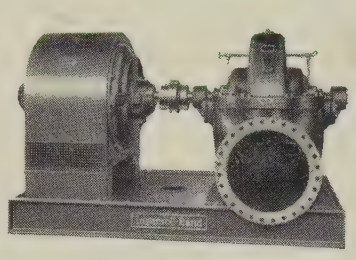
PUMPS MEAN RELIABILITY
for the pulp and paper industry

STOCK PUMPS feature the patented diverging-type impeller in classes EL, EM and EH. This unique design will handle paper stock heavily entrained with air—where other ordinary stock pumps will fail. In addition, the special impeller has handled various types of stocks from 7% to 8% consistency without the aid of a mechanical feed! Over 10% stock has been pumped with a screw-feed arrangement on the suction. For lower stock consistencies and where there is no air problem, classes CL, CM and CH pumps having a conventional impeller can be furnished. For all classes—heads: To 225 ft; capacities to 7000 gpm; sizes 4, 6, 8, 10, 12 inches.



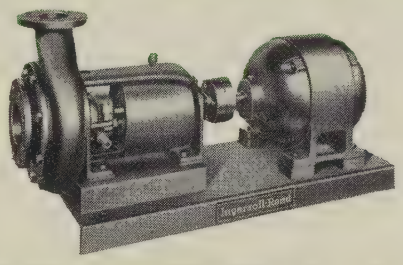


FAN PUMPS of single-stage, double-suction design are ideal for handling comparatively large volumes of liquids at low and medium heads. These pumps may be driven by any type of prime mover, and embody thoroughly modern design features that increase efficiency, insure reliability and lower maintenance costs. Capacities to 60,000 gpm.

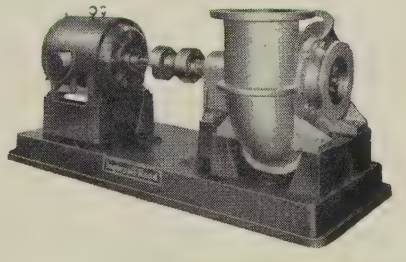


BULLETIN 7296 gives you further specifications and descriptions of all Ingersoll-Rand pumps for the pulp and paper industries. Its 24 pages are filled with cross-sections, data and installation photographs of I-R pumps at work in pulp and paper mills. For your copy of Bulletin 7296, contact your nearest I-R representative or write Ingersoll-Rand, 11 Broadway, N. Y. 4, N. Y.

CHEMICAL PUMPS are offered in a complete line for handling hot and cold acids and alkalis. They are single-stage units of end-suction design that are ruggedly constructed to last longer on the job. For handling highly corrosive liquids, these pumps are built of IRCAMET, a high nickel-chromium-molybdenum alloy steel that is corrosion resistant. Heads to 200 ft; capacities to 4000 gpm.

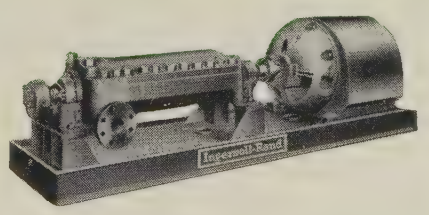


MIXED AND AXIAL FLOW PUMPS have a simplified construction that means fewer parts and less maintenance. Mixed-flow BPM propeller type is specifically designed to deliver large capacities at moderately low heads. Class APL axial-flow pumps are specially designed for handling large volumes at low heads. For both classes—heads to 40 ft; capacities to 20,000 gpm.



VERTICAL PUMPS are designed to handle liquids at heads ranging from a few feet to many hundreds of feet. Heavy-duty construction and high efficiencies are featured. Pump lengths and discharge locations can be furnished to suit the application.

BOILER-FEED AND DEBARKING PUMPS come in three types, each with symmetrical case and Unit-Type rotor design for easier maintenance and better operation. CNTA pumps are horizontally-split units available in 1-1/2, 2, 2-1/2 and 3 inch sizes. Capacities to 700 gpm; pressures to 1000 psi. HMTA pumps are horizontally-split units available in 2, 3, 4, 5 and 6 inch sizes. Capacities to 1600 gpm; pressures to 1200 psi. CHTA pumps are of "double-case" construction with vertically-split, forged steel outer casing. Available in 3 through 12 inch discharge sizes. Capacities to 7200 gpm; pressures to 6500 psi.



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Roll failure at any *one* point means costly equipment downtime and production slow-downs *throughout the mill*. Advanced roll covering facilities and skilled craftsmanship at Manhattan assure trouble-free roll performance at lower costs for every stage of your papermaking operations. Manhattan roll engineers have developed an inseparable bond of rubber-to-metal that eliminates cover separation. Manhattan cover compounds won't harden, crack, corrugate or oxidize . . . require fewer regrindings under the most extreme conditions of use.

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Let a Manhattan specialist show you how you can get better, longer roll service . . . "More Use per Dollar" . . . with Manhattan Press and Suction Press Rolls, Rub-Roc, Sham-Roc, Self-Skinner and Coating Rolls, Sealed-End Couch Rolls and Marblex Table Rolls.

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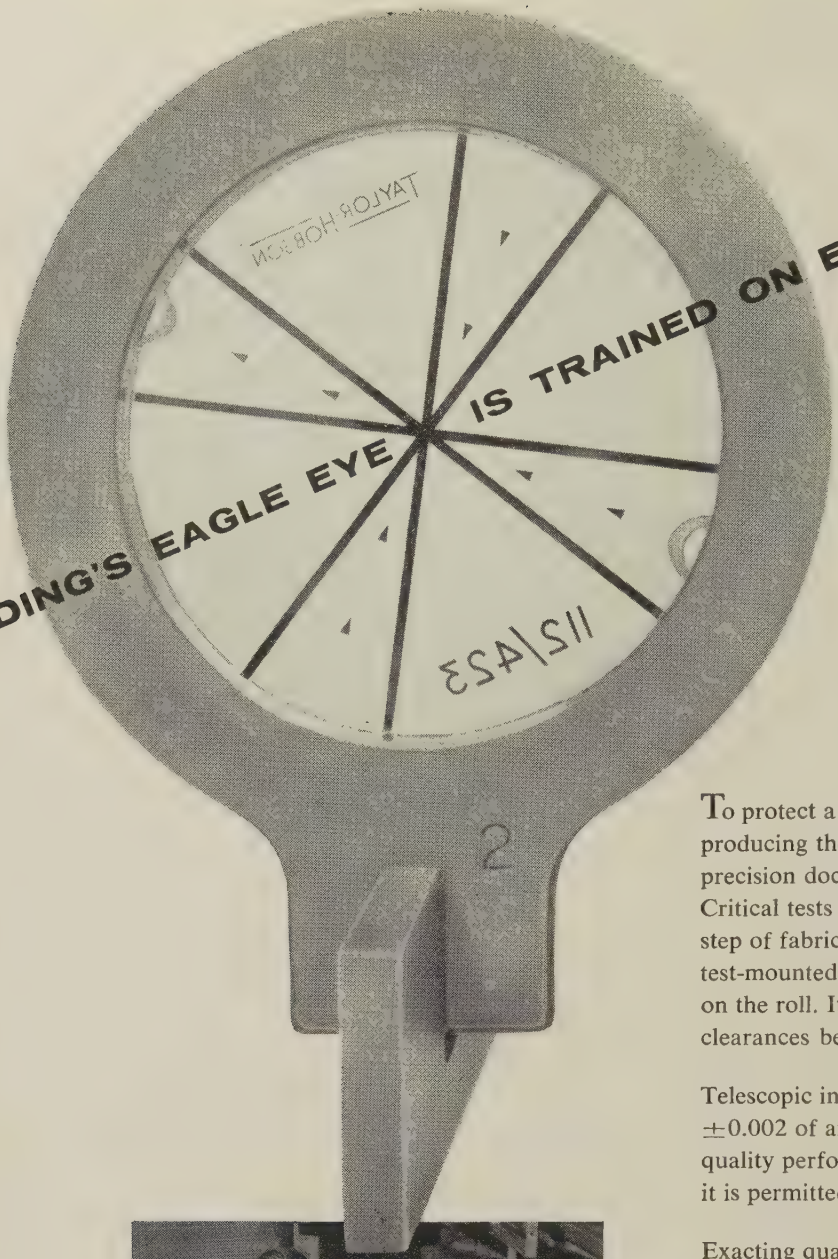
Calender dyes and colors dispersed in alginate solutions have improved flow properties, better laydown and far less mottle. You produce sheet surfaces ideal for color printing, yet without any hydrophobic characteristics to interfere with subsequent high speed gluing. For Kelco alginates provide maximum holdout of the dyes and colors for finest quality printing at reduced costs. To end your color migration problems, get the facts and begin using Kelco alginates.

YOURS ON REQUEST: Technical Bulletin details latest data on Kelco surface sizing agents including specific solutions to problems of improving densometer, printability, uniformity, smoothness, reduction of machine down time.

products of **KELCO COMPANY**

LODDING'S EAGLE EYE IS TRAINED ON EVERY DOCTOR



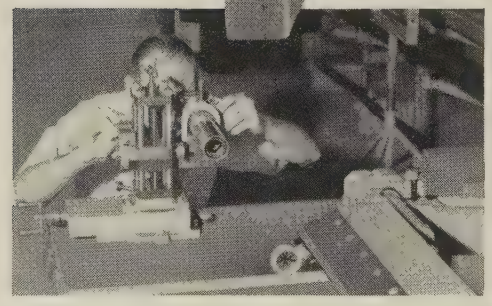
To protect a world wide reputation for producing the ultimate in custom-engineered precision doctors, Lodding spares no effort. Critical tests and inspections accompany every step of fabrication. Finally, each doctor is test-mounted in the exact position it is to occupy on the roll. It is then checked for tolerances and clearances before installation.

Telescopic inspection, assuring edge linearity to ±0.002 of an inch, is but one of many tests for quality performed on each Lodding doctor before it is permitted to leave the plant.

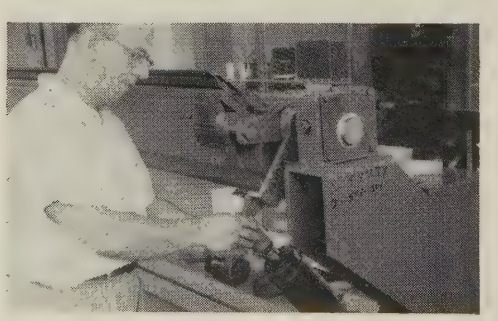
Exacting quality control and research combined with unique specialization in doctor engineering are among the reasons why Lodding doctors out-perform others in thousands of installations here and abroad.

Whatever your doctor requirements, from Fourdrinier to reel, you'll get exceptional value and performance from Lodding, recognized for leadership in precision doctoring.

Call on Lodding or your nearest sales representative for complete technical information at any time.



Telescopic inspection of blade holder



Testing complete doctoring equipment in operating position.

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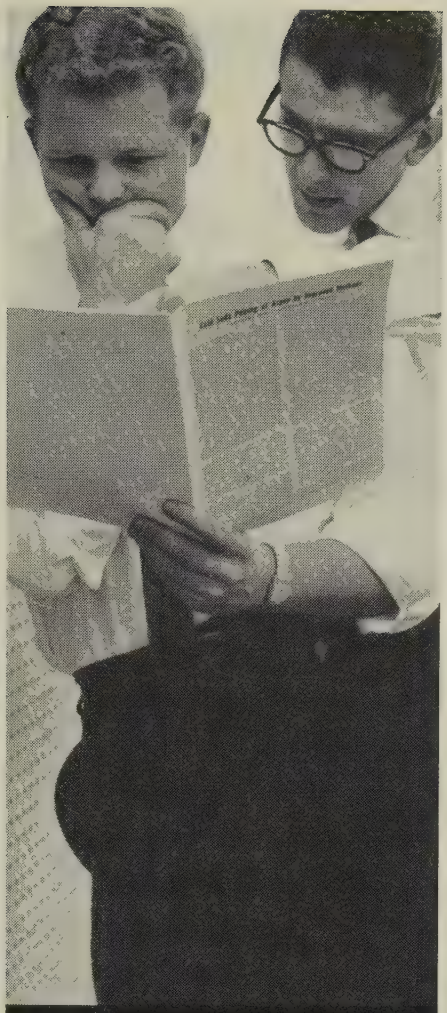
TWO BULLETINS FROM HOOKER ON COLD SODA PULPING

Special Considerations toward Improvement of Cold Soda Pulping Process. This recent paper gives results from experimental and practical work with southern red oak, white oak, soft maple, elm, ash, and yellow birch pulps.

The work was directed toward ways to improve the quality of paper and boards made from these various hardwoods. Charts and tables summarize data on such liquor absorption factors as pressure, vacuum, particle size, moisture content, surfactants, and presteaming.

This bulletin is a reprint of a paper prepared by Kenton J. Brown, chemical engineer of the Forest Products Laboratory, Forest Service, U. S. Department of Agriculture. Circle 252 on the coupon for a copy.



Cold Soda Pulping of Aspen by Improved Methods describes the results of work done under Hooker sponsorship at the Forest Products Laboratories. It describes a practical process for developing corrugating board and news-type papers from cold steeped aspen pulp. The resulting board shows higher strength properties than four other boards made from commercial neutral sulfite semi-chemical pulp. The paper showed itself suitable in every way for magazine-type book papers. The bulletin discusses the process and its results in detail. Circle 250 on the coupon for a copy.

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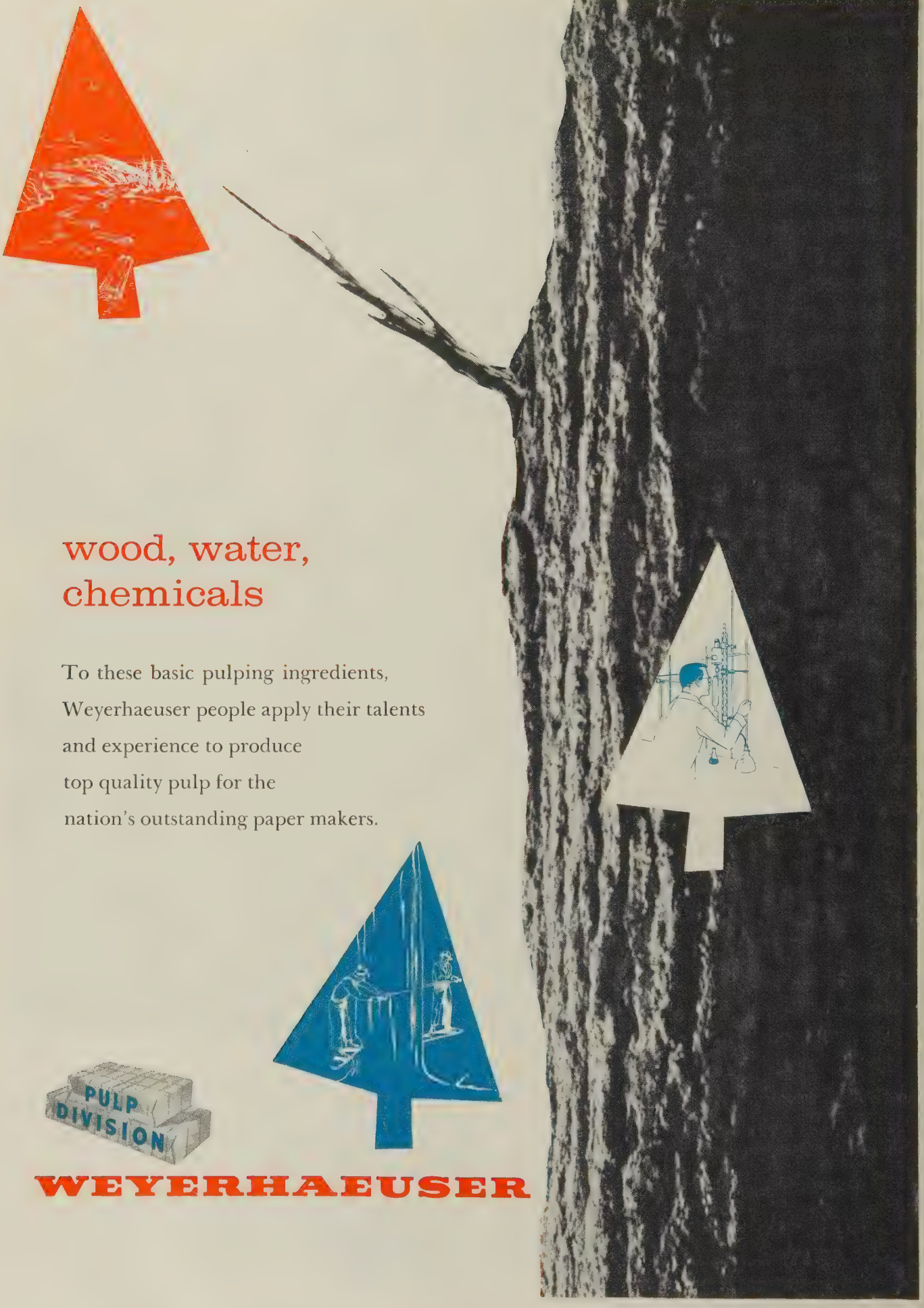
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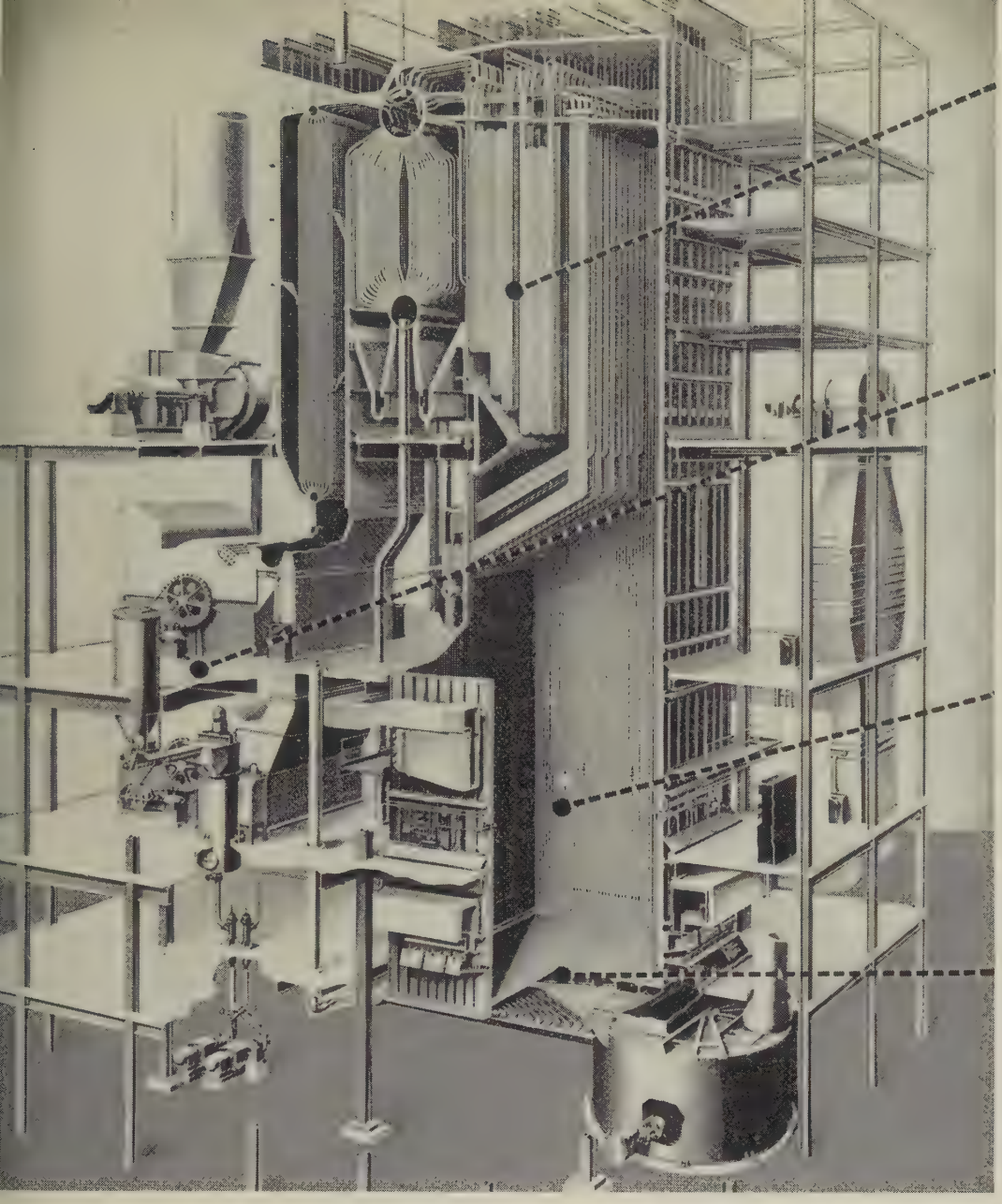

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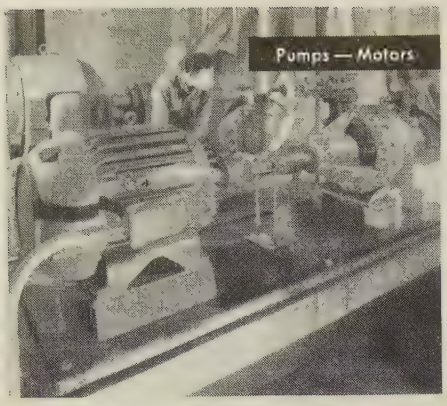

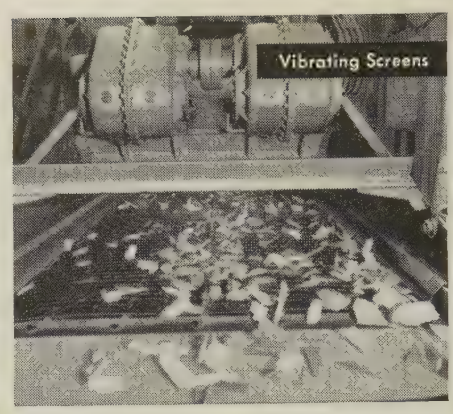

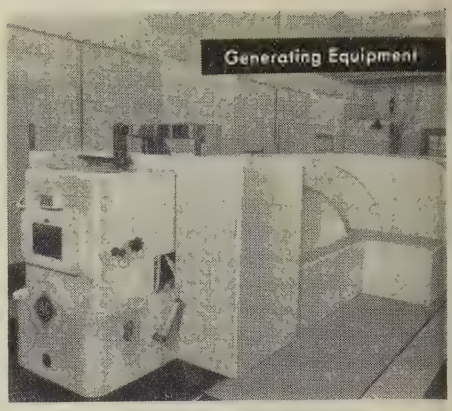

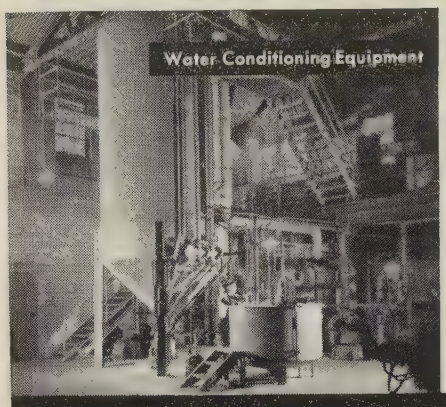

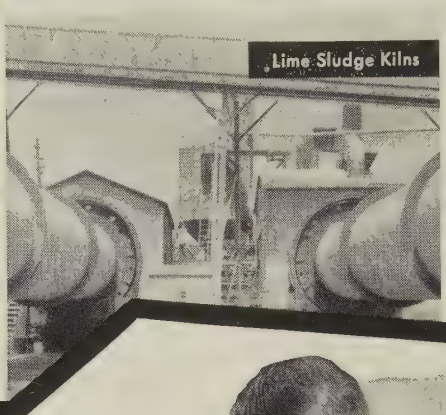

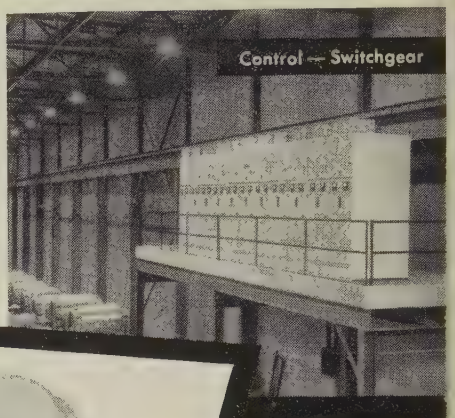

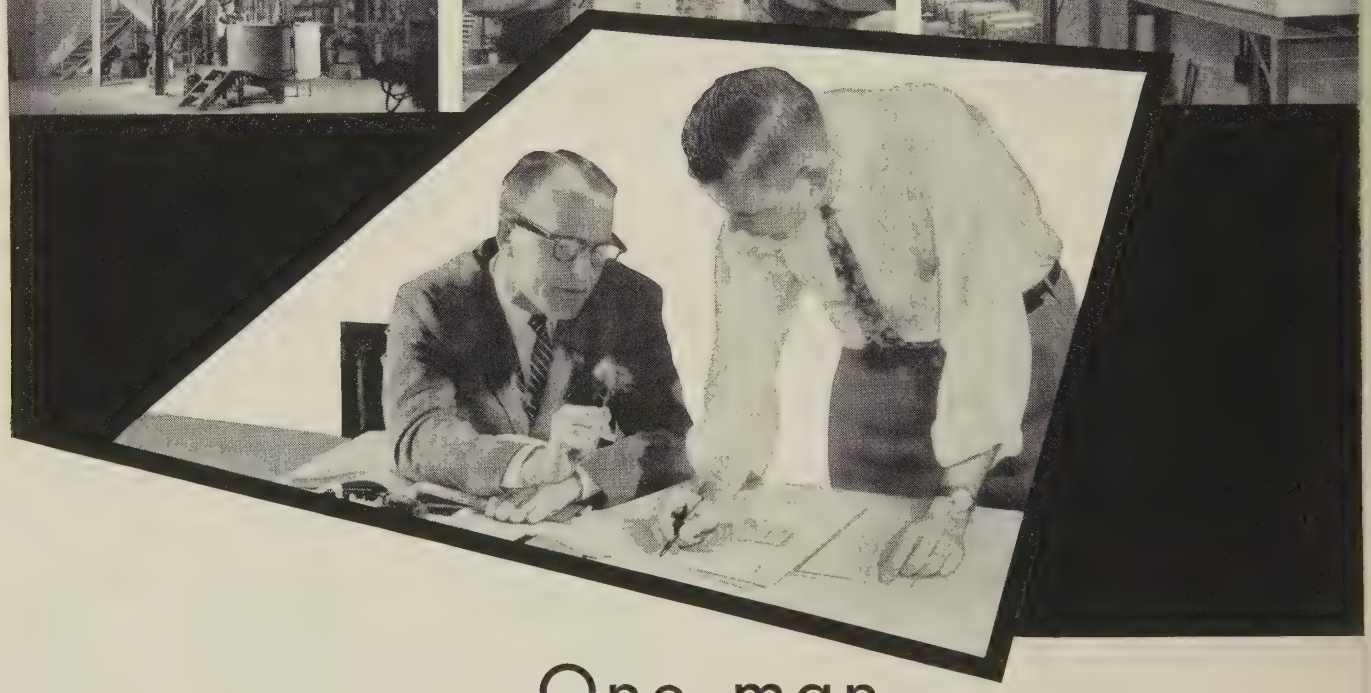

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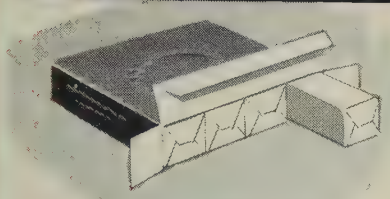

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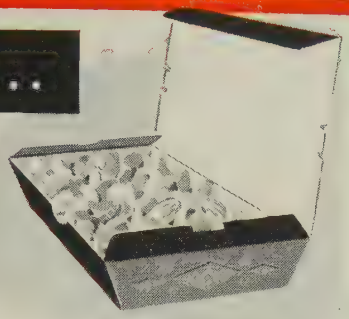

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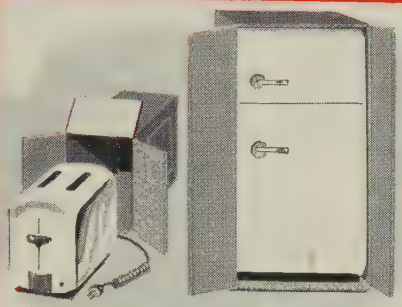

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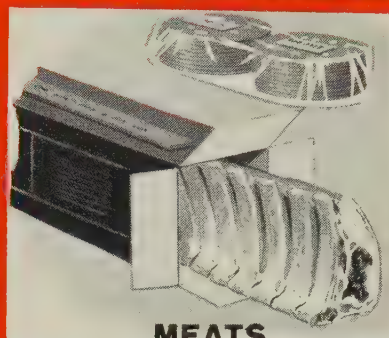

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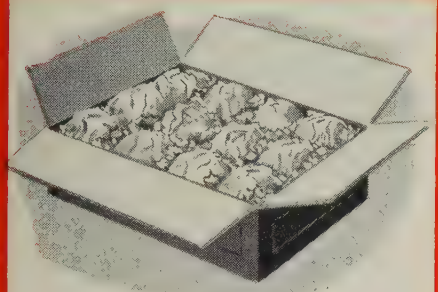

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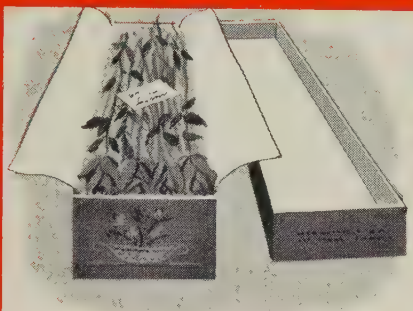

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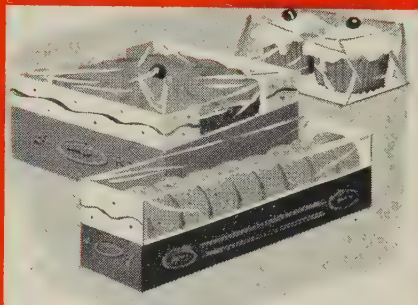

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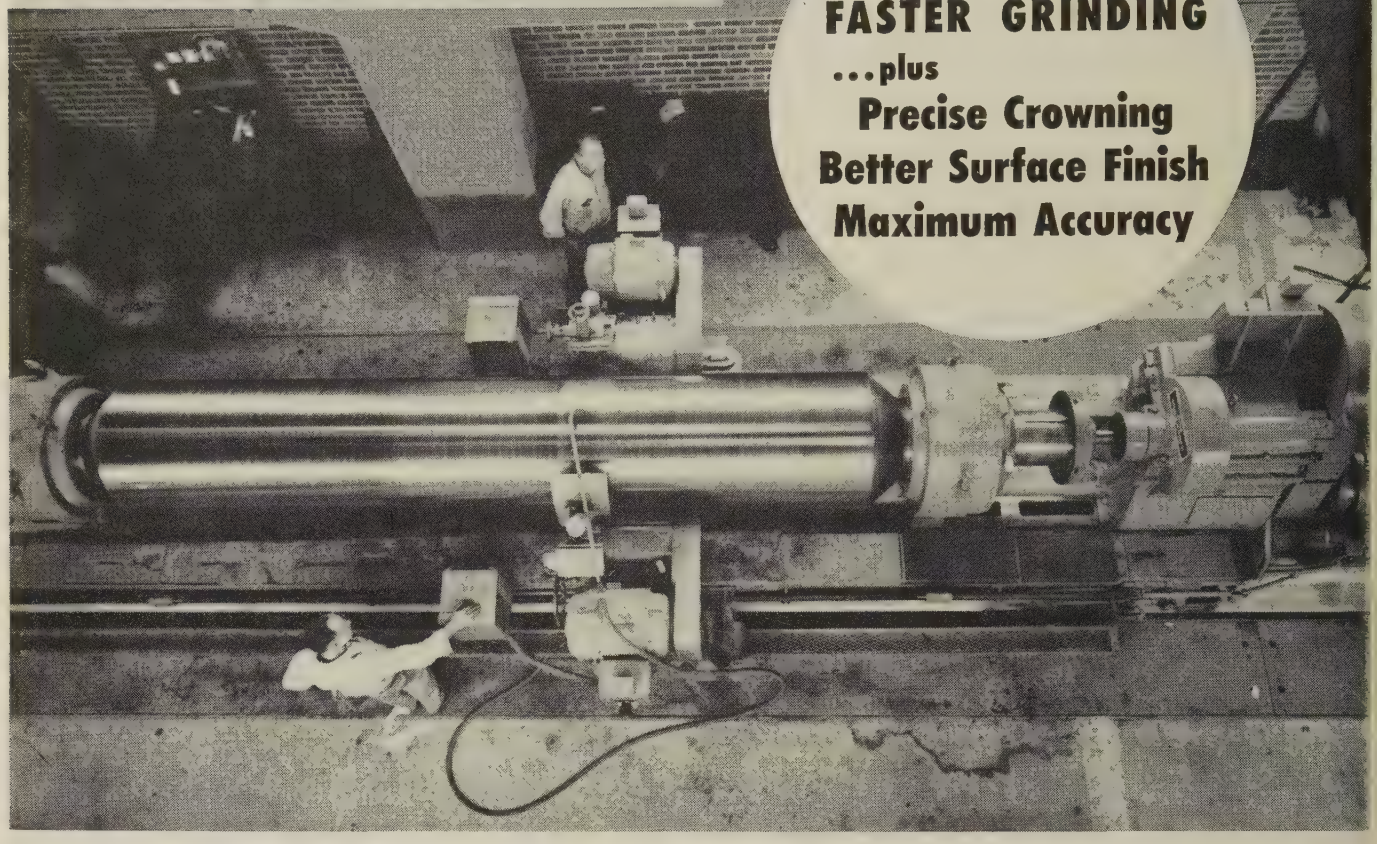

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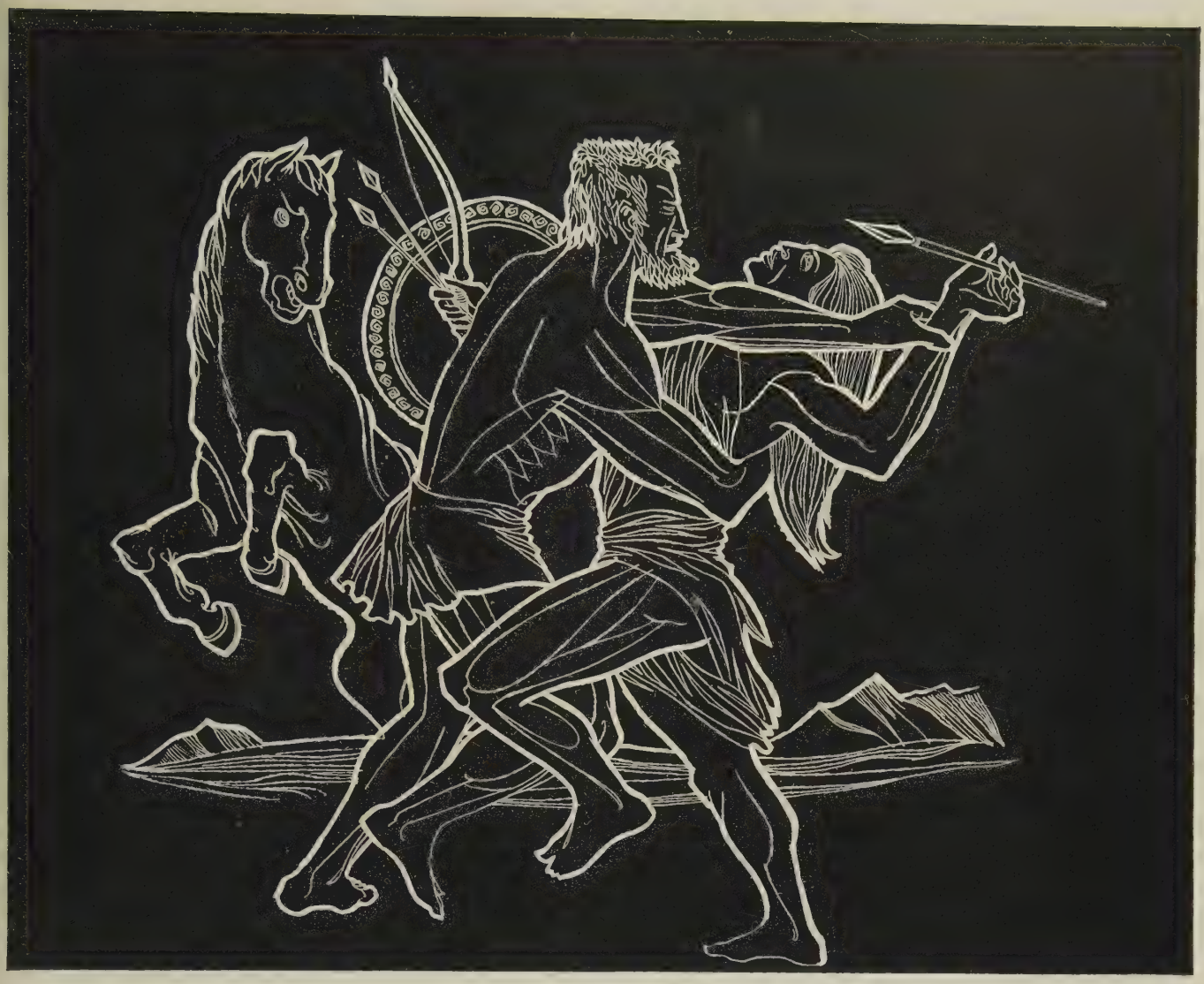

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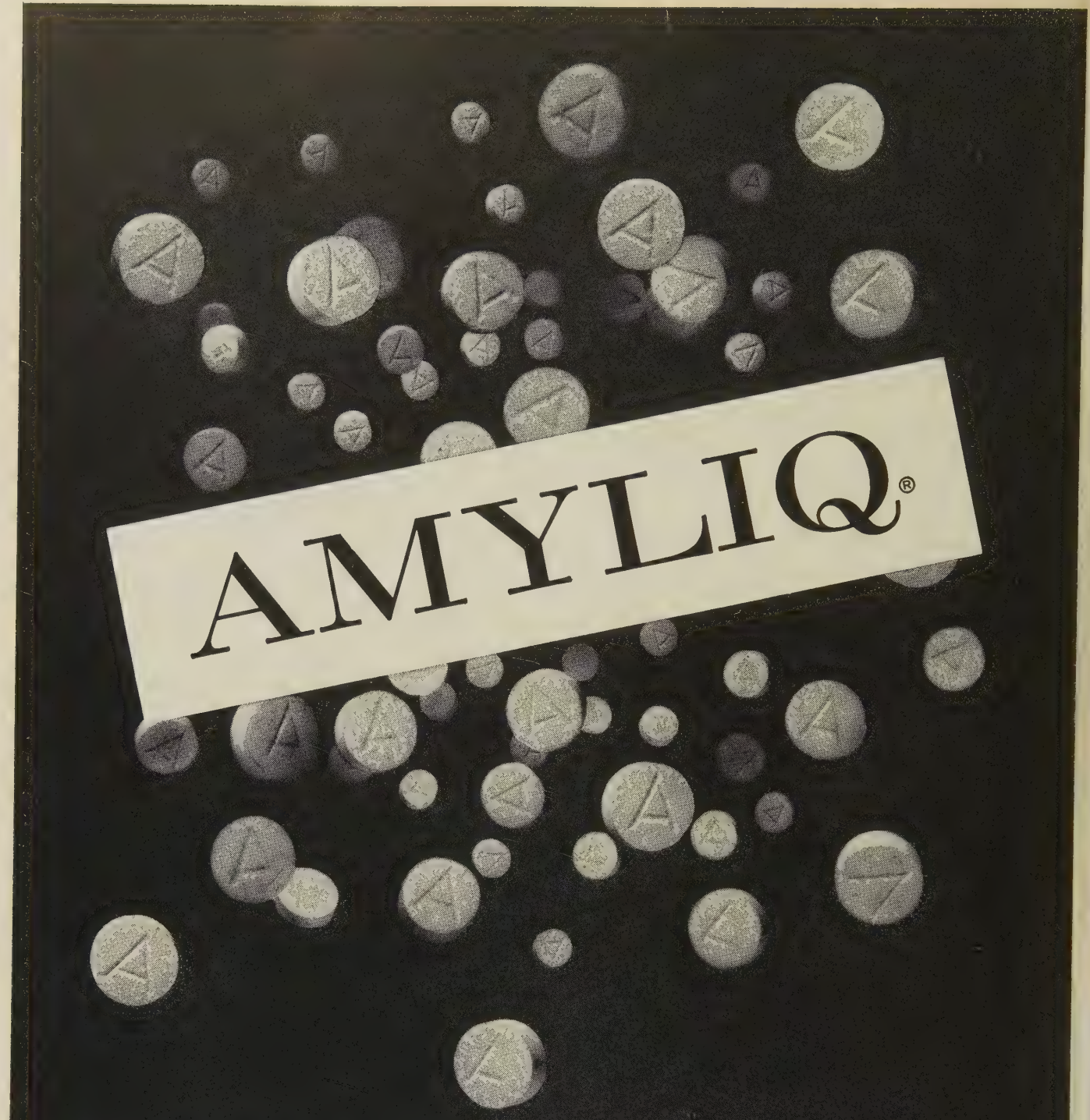

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Principles of Adhesion on a Paper Machine

B. RADVAN and G. O'BLENES

An apparatus for the measurement of adhesion of wet web to solid surfaces, at speeds approaching those of slow paper machines, is described. Measurements show that tension necessary to overcome adhesion has a minimum at slightly negative values of the angle of draw-off. The existence of such a minimum explains the instability of open draws noted by previous investigators. Adhesion increases with increasing speed of separation at positive angles of draw-off, but is independent of it at negative angles. Little effect of small changes in moisture content, and in the smoothness of the surface, has been found. Theories of adhesion of materials other than paper are discussed. Laboratory experiments on the starting of tears in wet web by means of standard size adhesive spots, and on the rate of spreading of tears, are described. Tears start more easily at positive angles of draw-off; at negative angles, the web tends to skin rather than tear through. Also, as the angle of draw-off decreases, the tears, once started, spread more slowly, and may even become self-healing. A second type of self-healing break may also result from two tears running close together at a moderate value of the angle of draw-off. Machine experiments confirm these findings. It is thought that self-healing breaks of the first type are uncommon, those of the second type more frequent. The need for further research is discussed.

THREE recent papers (*1*, *2*, *3*) testify to the interest in the subject of adhesion of wet web to the solid surfaces of the paper machine, because of the recognized close connection between adhesion and the occurrence of web breaks in an open draw.

Reference (1), in particular, marks an important advance in the understanding of the subject, through deriving the relationship between the work of adhesion and tension of the web. However, no actual measurements of adhesion were reported.

Consideration of the theory of tacky adhesion has led us to believe that such measurements are essential if the behavior of the web in an open draw is to be understood (*10*). Also, we have found no record of any study of the complex phenomena involved in the breaking of the web in an open draw. Accordingly, we have carried out investigations into these subjects along the following two lines of approach: (1) to measure, in the laboratory, the work of adhesion at speeds approaching those of paper machines, and (2) to simulate, in the laboratory, the conditions under which paper web breaks in an open draw, and also to study such breaks on an actual machine using a cine camera.

MEASUREMENTS OF ADHESION OF WET WEB TO SOLID SURFACES

Apparatus

Rectangular sheets of known basis weight, were formed on the BP & BMA standard sheet machine, and pressed on to stainless steel plates. The sheets were then pulled off by means of a long thread which was attached to the circumference of a light, balanced wheel at one end, and clipped onto the sheet, at the other. The wheel was mounted with its axis in the horizontal plane. The fall of a weight attached to the circumference of the wheel produced the required velocity; the height to which it rose gave measure of the work done in peeling.

The angle at which the sheet was pulled off was controlled. Figure 1 explains the definition of the angle, and cine photographs confirm that it remained steady during any one experiment. In order to avoid dragging the sheet on the floor, after it had been pulled off, the thread was attached to the wheel by a simple self-disconnecting device. The radius of the wheel was 32.5 cm.; its moment of inertia, 3.8×10^5 g.-cm.^{2}

Method

A bleached sulphite pulp, beaten to 28°S.-R., was used in all experiments. A 64-mesh twill wire was used in the sheet mold instead of the standard 120-mesh, care being taken to cut all sheets in the same direction as the warp. A copper template resting on the wire, 6.35 cm. wide by 14 cm. long was used for producing rectangular sheets. Two weights, 26 and 85 g. mounted on the wheel, produced peeling speeds of 94 cm. per sec. (185 f.p.m.) and 151 cm. per sec. (300 f.p.m.). Again, cine photographs confirmed that the speeds were constant and approximately equal to the calculated value.

The work done in peeling the sheet was measured as the difference in the height to which the weight rose when pulling the sheet off the surface, and the greater height to which it rose when pulling a similar sheet rolled up in a cylinder, and resting on the plate.

In most experiments, the sheets were transferred onto stainless steel glazing plates, and pressed according to the BP & BMA standard method. The dry content varied from 35 to 40% total weight. In some experiments the glazing plates were replaced by other solid surfaces. Finally, sheets were pulled directly off the wire, at a dry content of 17 to 21% total weight. A special technique, resembling that used in reference (4), was developed in order to obtain such high dry contents.

Interpretation of the Results

In the early experiments, the recorded value of the work done was divided by the area of the sheet stripped off the surface, and expressed as work of adhesion per unit area. We soon found, however, that the work required to peel off the sheet was not proportional to the area stripped off, but only increased linearly with it. A typical set of results is shown in Fig. 2.

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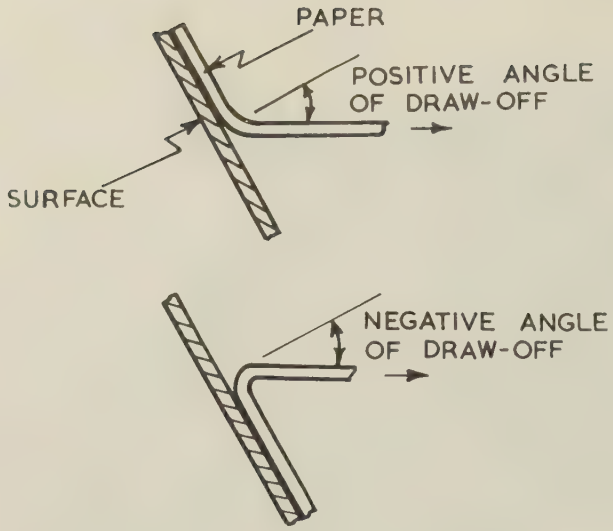

Fig. 1. Definition of angle of draw-off

The slope of the graph, divided by the width of the strip, represents the increase in work necessary to peel off a unit area, and therefore is a true measure of the work of adhesion.

The intercept of the graph, i.e., the fairly large amount of work necessary to start off the peeling, is more difficult to interpret. It changes in a regular manner with both the speed and the angle of draw-off, as shown in Fig. 3. It probably represents the initial viscous flow of the film of fluid between the sheet and the surface, before cavitation begins (see discussion following). In any case, this initial quanitity has no counterpart in the continuous operation of an open draw on a paper machine, although it may be relevant to the problems of sheet transfer.

The wide scatter of the results shown in Fig. 2 is a common feature of all peeling tests (*5*, *6*). The solid lines drawn through the points have been determined by the method of least squares; the accuracy of their

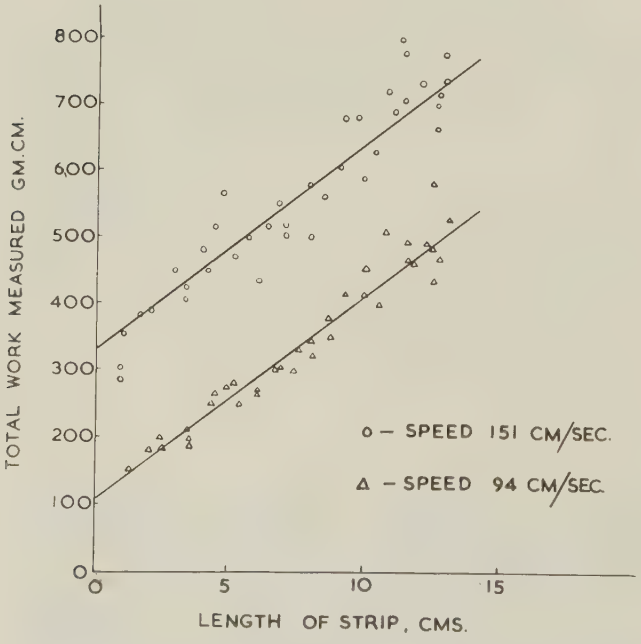

Fig. 2. Effect of the stripped area on the work of adhesion

slopes can be calculated and amounts to approximately 15%. Much less scatter was found when peeling the sheet directly off the wire, possibly because the variations in transfer and pressing were avoided.

At these speeds the work done in imparting kinetic energy to the sheet is small, and has been neglected.

When divided by the quantity $1-\sin\theta$, where θ is the angle of draw-off, as in Fig. 1, the work of adhesion becomes numerically equal to the tension of the sheet (*1*). Since this is the technologically more important quantity, most of the results have been expressed as tension (see Figs. 3, 4, and 5).

Results

Effect of the Angle of Draw-off. Figures 4 to 7 show that, in all cases, the work of adhesion decreases from a

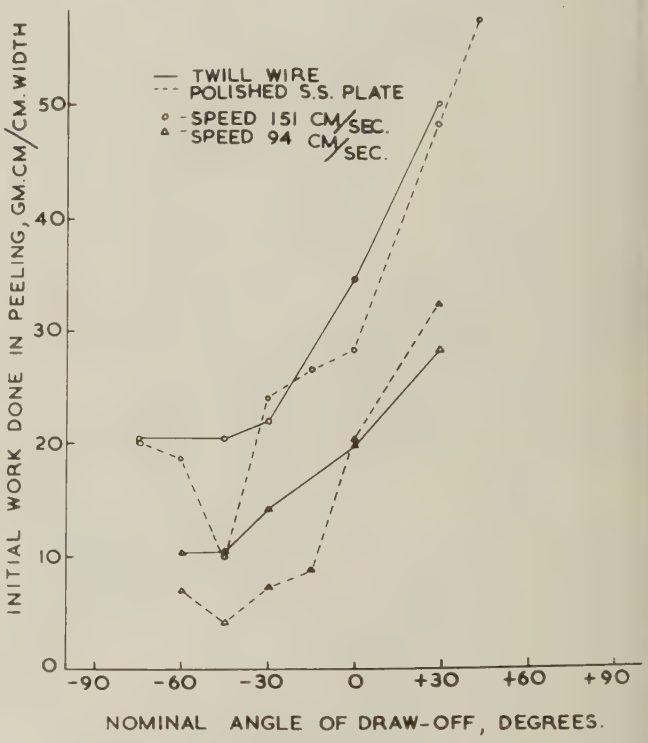

Fig. 3. Work necessary to start peeling

large value at positive angles to a minimum at an angle of $-30°$ to $-40°$. When expressed as tension, the difference between the positive and negative angles becomes even greater, but the minimum is not so pronounced.

Effect of Speed. Figures 3 to 6 show that the work of adhesion is much larger at the higher speed, when the angle of draw-off is positive. At small positive, or negative angles, this difference disappears.

Effect of Surface Roughness. Two polished granite surfaces,* and a fine sand-blasted stainless steel surface are compared with the ordinary polished stainless steel glazing surface in Fig. 7. The index of roughness used in the comparison is an average value obtained on a proprietary surface-profile instrument.† The only outstanding difference shown in Fig. 7 is the lower value of adhesion found with the very rough surface of the sand-blasted plate.

Effect of the Dry Content of the Sheet. During the early experiments, the dry content of each sheet was

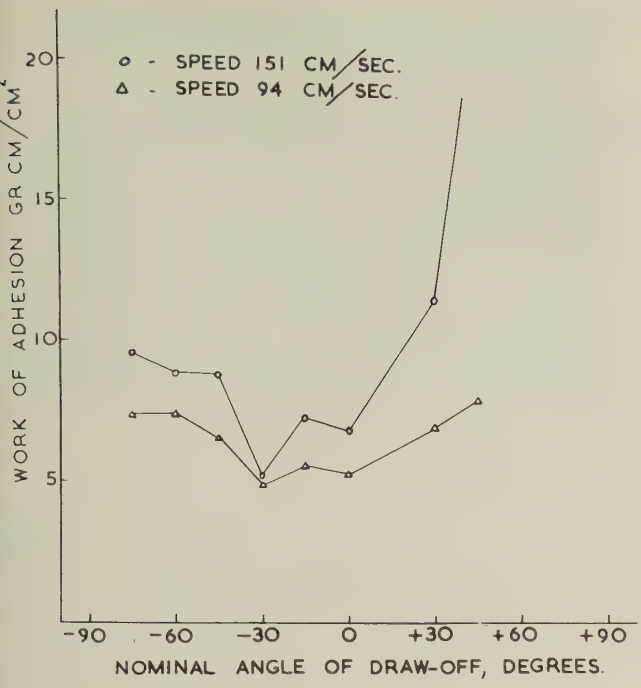

Fig. 4. Adhesion of wet web to 5.5 glazing plates

determined after the test. No significant differences were found in the range investigated (35 to 40% dry, on plates, 17 to 21% dry on wire), but the adhesion fell off significantly if the dry content exceeded 40% on plates or was less than 17%, on wires. Such sheets were rejected.

Discussion

Very little systematic work on the adhesion of wet paper webs to solid surfaces has been reported. In 1944, Haeger and Soderlund (7) measured the maximum basis weight of board which could be supported by adhesion to the underside of a wet felt. They found that adhesion increased with beating, with

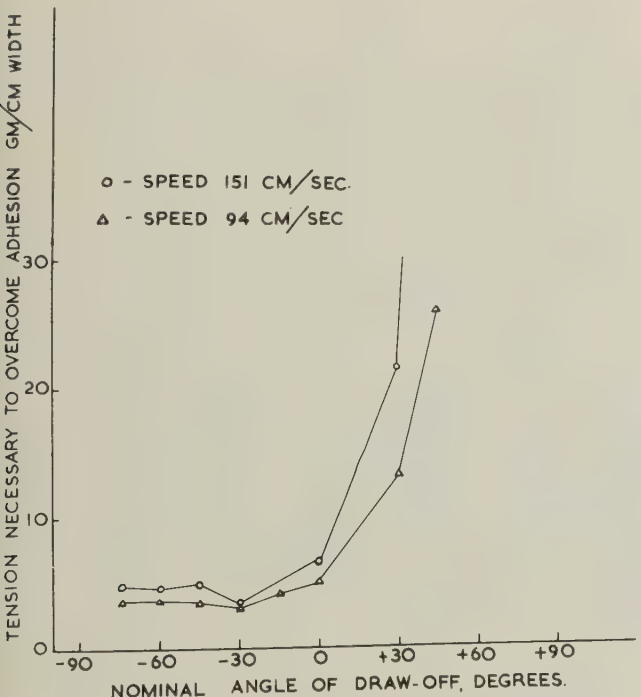

Fig. 5. Adhesion of wet web to S. S. glazing plates

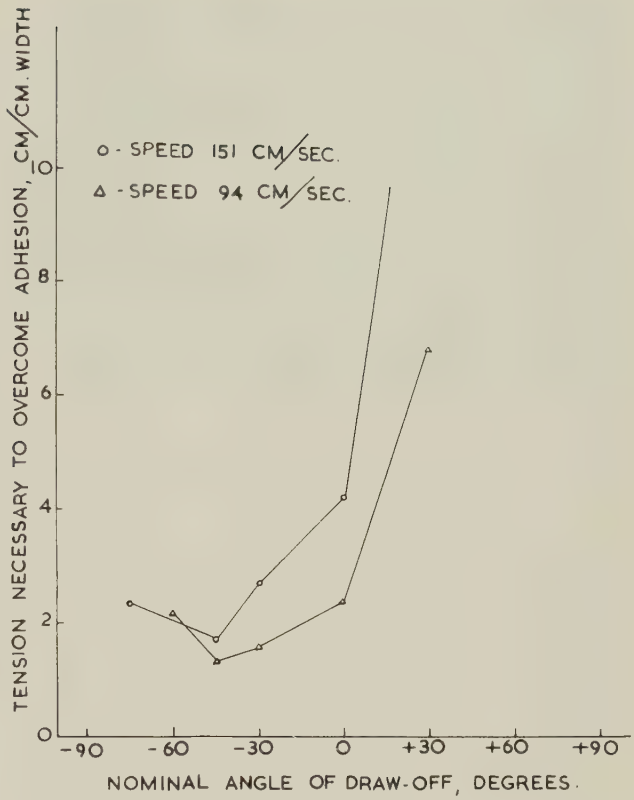

Fig. 6. Adhesion of wet web to 64 meso twill wire

speed of the machine, with increased sulphite content, and with lower couching pressure, but was not affected by the degree of sizing, the forming pressure, or the consistency. This measurement appears more

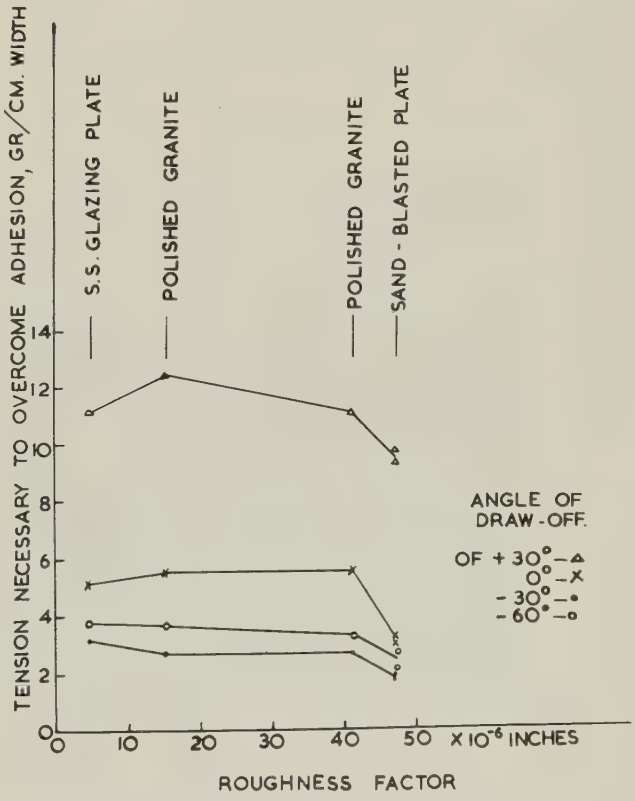

Fig. 7. Effect of roughness on adhesion

closely related to the initial work of separation, as discussed above under "Interpretation of Results," than to the work of adhesion per unit area.

Edge, in an unpublished work carried out in this laboratory *ca.* 1947, found that adhesion passed a maximum at approximately 60 to 70% dry content, different surfaces giving different values. The measurements were carried out at very low speeds, and without controlling the angle of draw-off. More unpublished work at the Bridgend Paper Mills Ltd. in 1953, showed that there was little effect of speed in the range 200 to 600 f.p.m., and at a constant angle of draw-off of 0°. Again, a distinct maximum was found at 60% dry content. These results are most nearly comparable with ours: the absence of the effect of speed may have been due to the measurements being carried out at this particular angle (see "Results" above); but the maximum occurred at a much higher dryness content than in our experiments. None of these measurements allowed for the initial work of separation.

References (1) and (3) give a value for the work of adhesion of approximately 1800 ergs per cm., which is comparable to our results. No experimental details are given, but the measurement was carried out at a very low speed.

Outside of the paper industry, a number of descriptions of peeling tests may be found (*5, 6*). The importance of the speed and angle of draw-off are well recognized, but the materials being tested (surgical plaster, adhesive tapes, etc.) are very different from paper and water. The printing industry supplies a closer comparison. Here, a number of workers (*5, 8*) investigated the splitting of a layer of ink between the rapidly separating surfaces of two rollers. The overall conclusions seem to be that, at slow speeds, the layer of ink flows against the resistance of viscous forces, into thin "necks" which then break by tension. At higher speeds, cavitation occurs, and the film breaks like a solid. Again, the effects of speed are well recognized, but those of the angle of draw-off are not considered, since they do not occur in roll-plate or roll-roll contact.

More theoretical studies of the forces preventing separation of solid surfaces have been briefly summarized (*5*). Stefan's formula (1874) for two circular plates immersed in a Newtonian liquid predicts that the force opposing separation is proportional to the speed of separation. A similar result was obtained by Healey in 1926, for plates joined by a drop of liquid. Experimental confirmation of Stefan's formula was recently produced by Strasburger (*9*), who measured such forces in thick oils at speeds of 1 to 12 f.p.m. At slow speeds Stefan's formula applies, but with increased speed, cavitation occurs and the resisting force falls well below the Stefan value.

There is little direct relevance to the present work in the above-reviewed investigations. Tentatively, one may suggest that similar mechanisms apply here; viscous flow at positive angle of draw-off, with resulting high values of the work of adhesion, and the pronounced effect of velocity; cavitation and elastic rupture at negative angles, with low values of the work of separation, and no effect of velocity.

The technological importance of the present findings lies in the demonstration of a region of minimum tension at slightly negative values of the angle of draw-off. The presence of such minimum explains the puzzling instability of the draw at negative angles, which has not yet been satisfactorily explained (*1*).

This instability may be explained as follows: consider a web pulled off at an angle of minimum tension. Let now the adhesion increase slightly. The tension is determined only by the speed ratio of the draw, which remains constant; it is, therefore, insufficient to overcome the increased adhesion. The line of separation moves down, the tension becomes even less sufficient, and the web will not be detached at all.

Several possiblities for further research suggest themselves immediately, such as investigating the effects of furnish, beating, and dryness. At higher speeds, not obtainable with the apparatus described here, the phenomena may well be quite different. The general subject of the splitting of thin films of water has not been investigated; nor has the connection betwen adhesion and sheet transfer.

ADHESION AND BREAKS IN AN OPEN DRAW

Again, the importance of this subject is indicated by the number of devices for, and publications describing the measurements of the tensile strength of wet web. Most papermakers will need little persuasion to convince them of the nuisance and financial loss caused by breaks in an open draw. However, we have failed to discover a publication describing the manner in which such breaks actually take place, except for some speculations by one of us published jointly with others in an earlier article (*10*).

Normally, breaks start through a spot in the web failing to be detached from the surface to which it adheres. Such a spot will move with the surface of the roll, and away from the rest of the web, producing a tear at the line of separation. The tear moves across the machine at a fairly constant speed until the whole of the web remains stuck to the surface. Three points immediately command attention in this description: (1) open draw breaks occur by tear, not by tensile failure; (2) a given type of fault in the web need not always cause a break; (3) breaks spread at a definite speed, which depends on machine conditions. Accordingly, we investigated in the laboratory the conditions which favor the occurrence of breaks, by using the following means:

1. A standard size sticky spot was placed on a glazing plate, and the sheet was then pulled off as before. Conditions were noted under which a break would or would not start.

2. A clean plate was used, but two cuts were made in the sheet in order to initiate the tear. The rate of spreading of such tears (i.e., the angle of tear) under different conditions, was noted. These observations are described in the following paragraphs.

The Starting of Breaks

Figure 8 shows some typical results on 30 and 50 g. per sq. m. sheets. The adhesive spots consisted of circles of a proprietary double-sided adhesive, of

* Samples of granite were kindly supplied by Millspaugh Ltd. and Walmsleys (Bury) Ltd.

† The instrument measures the average displacement of the profile of the surface in units of 1 microinch.

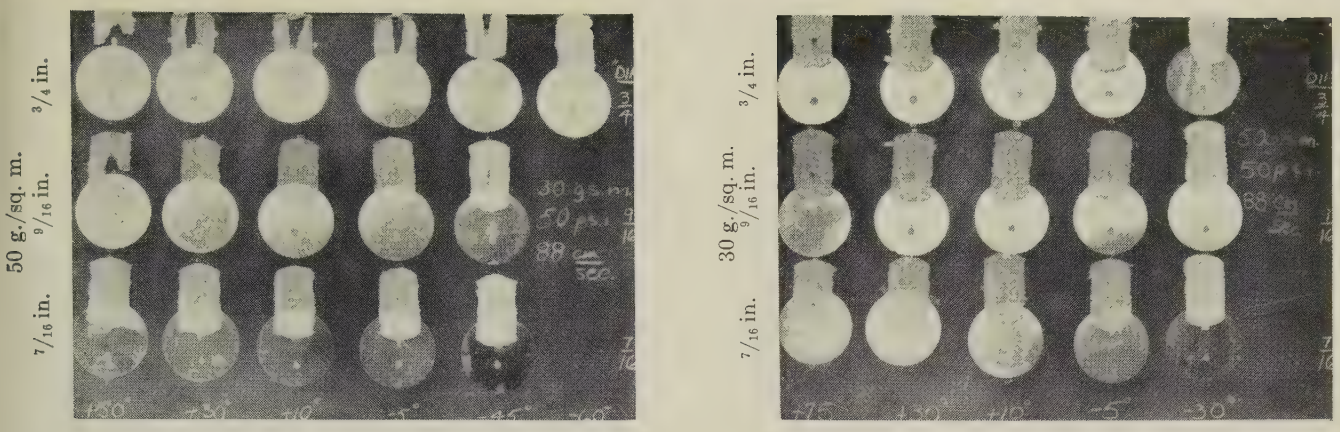

Fig. 8. Breaks produced by adhesive spots of different diameters

diameters $^{7}/_{16}$, $^{9}/_{16}$, and $^{3}/_{4}$ in. It will be seen that breaks occur with thin papers, large adhesive spots, and positive angles of draw-off. For a given basis weight, and the same size of adhesive spot, the sheet will break when pulled off at a positive angle, and will only "skin" at a negative one.

Cine camera shows that breaks do not start until after the line of separation has passed over the adhesive spot. A depression appears in the web, followed—if a break is to develop—by rupture at both sides of the spot, which then extends by tearing. The manner in which such tears then spread is further discussed below.

Even when no break occurs, the angle of draw-off affects the depth of the "skin" which is plucked out of the sheet by the adhesive spot. Figure 9 shows alpha radiographs of the thin areas left in the sheet pulled off the adhesive spot. The details of this technique are discussed in reference (11), but it amounts to "sectioning" the sheet at different depths. It will be seen that deeper plucking occurs at positive angles.

These experiments were repeated on a paper machine, by feeding similar circles of double-sided adhesive into the nip of the first press, between the paper and the granite top roll. At 270 f.p.m., making a 70 g. per sq. m. gumming base paper, very similar results were obtained and recorded on a film. Table I shows that breaks occurred at tight draws (i.e., positive angles of draw-off), while only skinning was produced at slack draws (i.e., negative angles). Figure 10 also confirms the laboratory predictions of the effect of draw tightness on the depth of plucking.

An important difference between the laboratory and mill experiments was noted: in the laboratory, the adhesive spots always stuck to the glazing plate and ruptured the paper; but in the press, they sometimes transferred onto the paper, so that no rupture occurred. Table I shows that such transfers occurred with tight draws (positive angles of draw-off), and with heavy line pressure.

The Spreading of Breaks

Figure 11 shows the sheets torn while adhering to glazing plates. In some experiments, the two out-

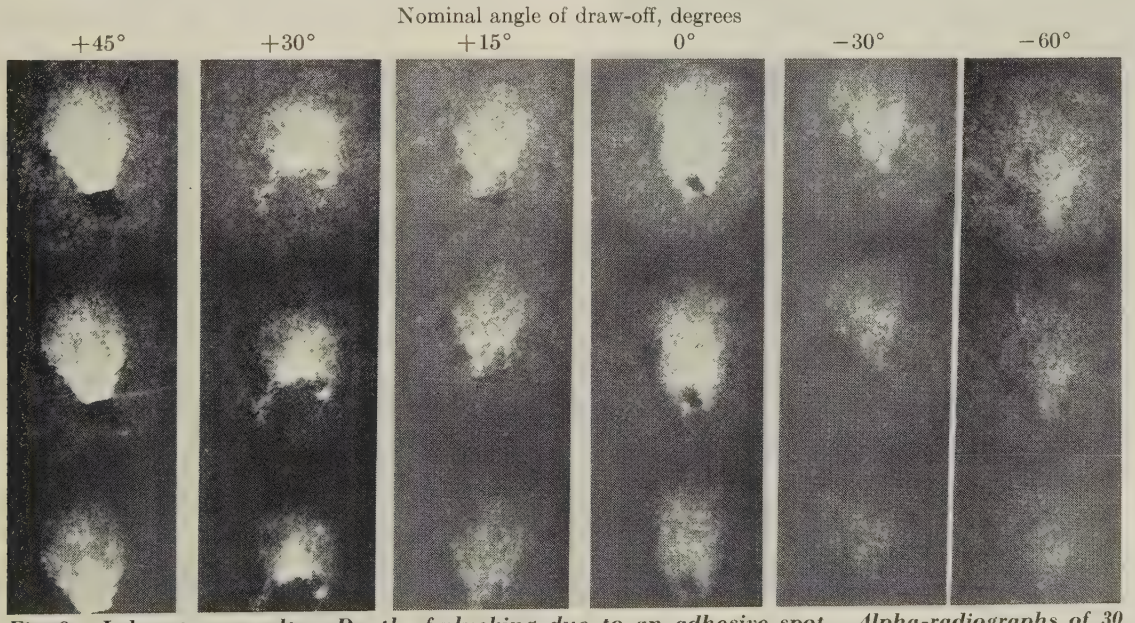

Fig. 9. Laboratory results. Depth of plucking due to an adhesive spot. Alpha-radiographs of 30 g/sq. m. sheets

Top row: Each spot corresponds to an area of substance, <24 g/sq. m. Middle: Each spot corresponds to an area of substance, <18 g/sq. m. Bottom.: Each spot corresponds to an area of substance, <12 g/sq. m.

Table I. Rupture of the Surface of Wet Web Due to an Adhesive Spot on First Press Roll 70 g. per sq. m. Gumming Base

Line pressure	*Diameter of spot, in.*	*Web tension*			
		Tight	*Medium tight*	*Medium slack*	*Slack*
Light	5/8	No	...	Skin	Skin
	7/8	No	...	Skin	Skin
	1 1/8	Break[a]	...	Skin	Skin
Normal	5/8	No[c]	Skin[b]	Skin	Skin
	7/8	Break	No	Skin	Skin
	1 1/8	No	Break	Skin	Skin
Heavy	5/8	No	No	No	No
	7/8	No	No	No	Skin
	1 1/8	No	No	No	Skin

[a] The spot plucks a hole out of the web.
[b] The web skins but does not break.
[c] No rupture (the spot transfers onto the web).

side parts of the sheet were pulled off, leaving the center part stuck to the plate; in others, the arrangement was reversed. In each case, the rate of spreading of the tear is shown by the angle at which the torn part, i.e., that adhering to the plate widens, as the tear progresses.

It will be seen that tears spread fast at positive angles, and run straight, or even tend to close, at negative angles of draw-off. The latter we shall term "self-healing breaks of the first type" because, if allowed to run, they will not spread across the web but instead will "heal," leaving an unbroken sheet.

Simple experiments on a paper machine confirmed these findings. The edge trim jet was pushed a few inches away from the weak edge of the web, so that a portion of the web now ran into the hogpit. On stopping the jet, the paper tore at the line of separation from the wire (another jet, placed, say 1 ft. away, stopped the spread of the tear). Observations and cine records showed that the tears spread fast when the

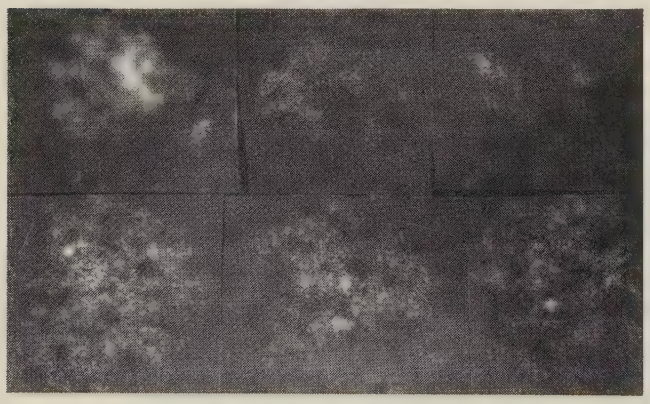

Fig. 10 Mill results. Depth of plucking due to an adhesive spot. Alpha-radiographs of 70 g./sq. m. sheets

Each exposed spot corresponds to an area of substance less than 24 g./sq. m. Top row, Spot size 5/8 in. diam. Bottom row, Spot size 1 1/8 in. diam.

draw was tight (i.e., angle of draw-off was positive), and ran straight, or closed, when the draw was slack (i.e., angle of draw-off negative). The same experiments were carried out on the draw from the first press with similar results.

A break, once started, may heal itself in another way, which we shall term "self-healing breaks of the second type." Such breaks may be seen in Fig. 11, when the outside strips of the sheet were pulled off at approximately 0° of draw-off, and the width of the central strip, left adhering to the plate was only 1/2 in. The tears closed up very quickly leaving a short, wide hole in the sheet. Cine camera records show that in these cases, the center strip is narrow

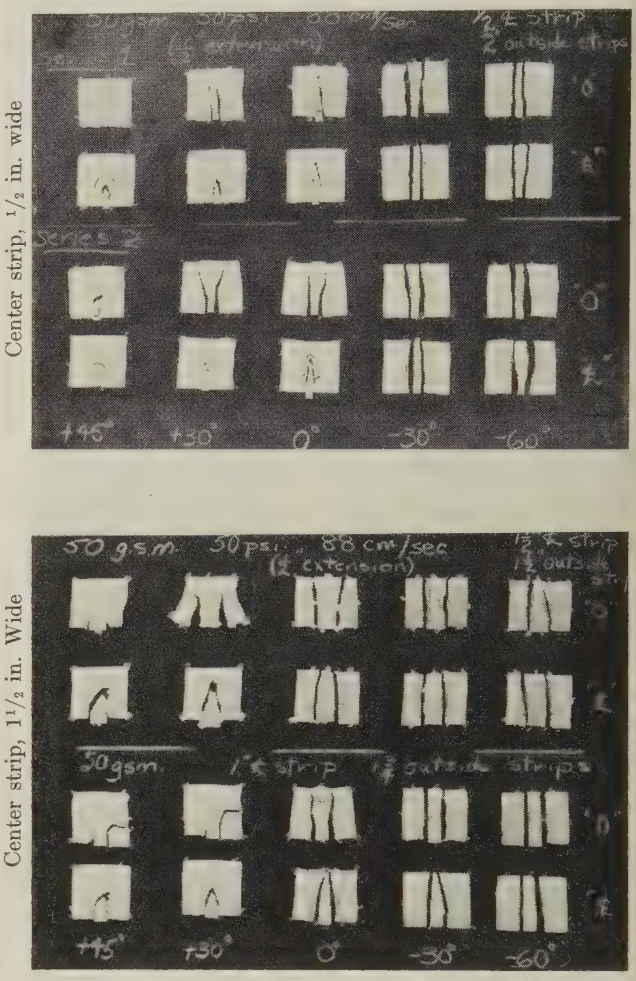

Fig. 11. Effect of the angle of draw-off on the spread of tears

"O," the outer part torn and center stuck. "℄," the center part torn and outside stuck.

enough to be lifted up and torn in the air, instead of at the line of separation. Inspection of Fig. 8 will reveal more such "self-healing breaks of the second type" produced at or near 0° of draw-off by the adhesive spots.

Again, the existence of these breaks in open draws of paper machines has been demonstrated by a similar experiment, and recorded on film.

A partial explanation of self-healing breaks is suggested by considering the shape of the web near the point of tear, as illustrated in Fig. 12. Similar shapes may be observed at slow speeds, e.g., when tearing a length of adhesive tape.

At positive angles of draw-off, failure occurs at a point inside that part of the web which has been already pulled off, resulting in the narrowing of that part and a fast spreading tear. At negative angles of draw-off, point of failure moves toward that part of the web

which is still stuck to the surface, resulting in a tear which spreads slowly, or even is self-healing of the first type.

When two tears are spaced closely together, the areas which are peeled off the surface along the line of the tears may overlap. This is more likely to occur at medium tight draws, resulting in self-healing breaks of the second type.

Discussion

Breaks in an open draw may also be divided into single tears, which originate at one and proceed toward the opposite edge, and double tears, which originate from a sticky spot in the center of the web, and extend toward both edges. In both cases, the speed of spreading of the breaks decreases as the draw becomes slacker and may become negative, resulting in self-healing breaks of the first type. Double tears may also become self-healing breaks of the second type if they are spaced sufficiently close together, and the draw is medium tight.

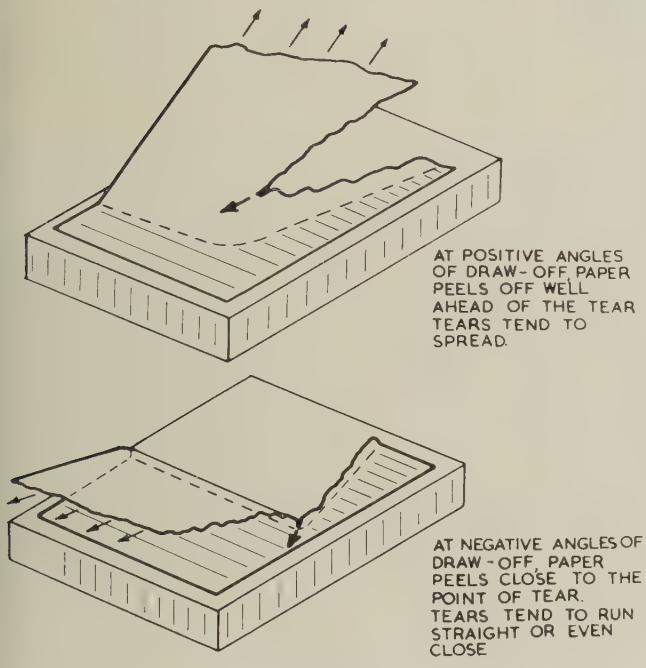
AT POSITIVE ANGLES OF DRAW-OFF PAPER PEELS OFF WELL AHEAD OF THE TEAR TEARS TEND TO SPREAD.
AT NEGATIVE ANGLES OF DRAW-OFF, PAPER PEELS CLOSE TO THE POINT OF TEAR. TEARS TEND TO RUN STRAIGHT OR EVEN CLOSE

Fig. 12. Observations of tearing

We do not wish to suggest that self-healing breaks of the first type are common, or that they may be produced on any machine merely by slackening the draw. In fact, we have only established their existence on two machines, making free, beaten, medium weight papers at speeds of 200 to 300 f.p.m.; on two other machines, making lighter papers at approximately 400 f.p.m., the draw instability explained earlier occurred before the speed of spreading of breaks became negative. In all cases, however, the speed of spreading decreased with decreasing angle of draw-off.

Self-healing breaks of the second type are, we suspect, much more common, since any faults in the web are unlikely to exceed $^1/_2$ in. width, and medium tight draws are quite usual. Having discovered these breaks late during this investigation, we only have records of them on one slow machine. However, one of the authors recollects having seen them on a tissue machine—an extreme example—without having then appreciated their significance. Unfortunately, the conditions for these breaks are such as to make single tears, starting at the edge, develop easily and spread rapidly.

The tempting possibility of running a paper machine under self-healing conditions clearly depends on its design, e.g., the length and position of the open draw, the nature and roughness of the adhering surfaces, the quality of felts, the liability to creasing, etc., and also on the running conditions—draw tightness, speed, the nature of the web, etc. Of these, we have only succeeded in investigating the effects of draw tightness. Research into the other variables will probably require pilot-plant experimentation, which could be better planned and made less costly if more was known about the mechanism of tearing.

Again, very little has been published on the subject. Most publications on tear either concern themselves with testing methods and apparatus used in quality control, or with the effects of beating, fiber orientation, etc., on the results of such tests (e.g., see *Tappi* and BP & BMA standard methods, and references (12) and (13). Tearing tests are also used in materials other than paper—i.g., solder, rubber, foils, fabrics (*5*); but the publications are no more informative.

It is generally recognized, however, that there are two kinds of tearing resistance: the initial resistance before the tear has started, which is related to the tensile strength, and the internal resistance to tears already started (*14*).

An interesting paper by Hennephof (*15*) describes the tearing of aluminum foils with a controlled angle of draw-off. The work of tearing is related to the amount of bending which is greater at negative angles. The constancy of the angle of tear and its dependence on the angle of draw-off are noted.

CONCLUSION

Laboratory measurements demonstrate minimum adhesion of wet web to solid surfaces at a negative value of the angle of draw-off. At that value, the draw becomes unstable.

At or near that value breaks in an open draw are difficult to start. When started they propagate slowly, and may even become self-healing. Breaks resulting from two closely spaced tears such as are produced by a small fault in the web, may also become self-healing at a moderate value of the angle of draw-off, due to another mechanism. Further research is needed to discover other conditions favoring the formation of self-healing breaks.

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Mrs. A. Rance carried out the photographic, and Messrs C. Dodson and A. Eales, the laboratory work.
We wish to express our thanks to the Board of Directors of W. T. & Co., in particular to Dr. H. F. Rance for permission to publish this paper.

Fundamentals of Adhesion from Molecular Forces in Cellulose

A. H. NISSAN

This study consists of five steps: (1) a brief review of cohesive forces and of cellulose structure is made, (2) a simplified model is then postulated, (3) a quantitative though approximate law of strength is formulated, (4) the theoretical relationship is checked against observations, (5) the model is refined in the light of observations. (1) Ultimately all cohesive and adhesive forces holding a sheet of paper together must be attributed to attractive energies between atoms. For polymers these are mainly (a) homopolar bonds exceeding 60 K cal. per g. mole; (b) hydrogen-bonds of about 4.5 K cal. per g. mole; and (c) van der Waals' bonds of about 1 to 2 K cal. per g. mole. Of these, the hydrogen bonds contribute most of the cohesion between cellulose chain molecules in paper sheets. The structure of cellulose is reviewed and it is concluded that the crystallites are perfect while the amorphous region is liquidlike. (2) The model of cellulose sheets is postulated as consisting of nonyielding rodlets in a homogeneous hydrogen-bond controlled amorphous region which takes the strain energy. (3) The theory is built around two concepts (a) a chain is as strong as its weakest link and (b) statistically, the larger the number of links in a chain the weaker will be its weakest link. Thus, long chains will be relatively weaker but, paradoxically, will require higher rupture energy than short chains. (4) The statistical theory is in reasonable quantitative agreement with observation. (5) From a more detailed study of the comparison with observation it is possible to refine the model and to estimate the van der Waals' as well as the hydrogen-bond contributions to the rupture energy.

An intriguing generalization about cellulose is that nature has anticipated, with a single exception, every major operation later invented by man and practised by the textile industry. Cellulose molecules are carded into thin sheets of elementary fibrils, drawn and spun into submicroscopic yarn, doubled and twisted into microscopic strands and ropes and, finally, even woven into durable sheets of the outer primary walls of cell plants (*1*). The single exception is knitting; there is no known structure in which the cellulose molecules are systematically tied in knots or formed into continuous loops. This observation is apposite in a symposium on cohesion. In all fibrous structures other than in knitted monofilament fabrics, the coherence of the structure depends upon the magnitude of forces resisting the tendency of its elements to slip past each other. But for the frictional forces between the fibers, all types of yarns, threads, and even woven cloth would fall apart. Even so it is with cellulose fibers, fibrils, and microfibrils down to the smallest element, the cellulose molecule. to understand the mechanism by which molecules form fibrils, fibrils combine into fibers and fibers into sheets of paper or board, it is essential to understand in general the forces, holding atoms and, in particular, two distinct molecules together. In a study of *mechanical* properties it is not usually necessary to go to a lower level than the molecule although, on occasion, severe mechanical stresses can result in failure at a submolecular level.

In this paper, an attempt will be made (1) to marshal known facts of observations and validated theories about intermolecular forces and cellulosic structures; (2) to postulate a model which will be an idealized and simplified version of the complex which occurs in nature; (3) to formulate a quantitative though approximate law for the strength characteristics of such a model under the simple condition of failure in a tensile test; (4) to check this derived relationship against observation; and (5) finally to take stock of how far the model represents nature.

BASIC FACTS AND THEORIES

We talk of "forces of attraction and repulsion" because of our subjective feelings in our muscular systems. In physical nature forces are space and time derivatives of the more basic concepts of potential energy and of momentum, respectively—entities which share with mass the important property of being conserved.

The energy of attraction between two particles may be defined as the energy required to separate them until they are infinitely apart. There are several types of such attractive energies acting between atoms and between molecules. As Bernal shows, however, the

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attractive energies which control most of the properties and particularly the mechanical properties of macromolecules are the three shown on Fig. 1 taken from his recent review paper (*2*). The strongest of these represent the homopolar bonds between the atoms constituting the molecule. They are due to sharing an electron by two atoms. They vary in strength but, generally, are greater than, say, 60 Kcal. per g. mole.

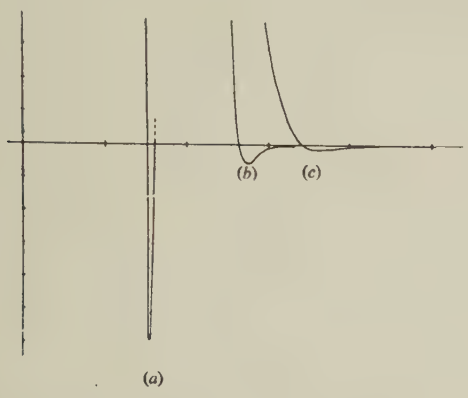


Fig. 1. Shape of energy curves for different types of interatomic forces (diagrammatic only): (a) homopolar bond, (b) hydrogen bond, (c) van der Waals' bond

Equilibrium distances between the atoms joined by such energies are small: from less than, say, 1 A. unit (10^{-8} cm.) to not more than 2 A. The high energies of covalent bonds are responsible for the atoms of the cellulose chain holding their places with respect to each other. Only when chains of macromolecules like cellulose are cross-linked to other chains by side-chains through covalent bonds (or the weaker ionic bonds of 10 to 20 Kcal. per g. mole) do such bonds contribute to the "adhesion" of chains to each other. This happens for example in branched chains of hemicelluloses and of starches which can give a three-dimensional network, probably in lignin-cellulose junctions in native fibers and in artificially substituting reactive side chains for some of the hydroxyl groups on the cellulose. Pure cellulose has no side chains.

The second type are the attractive energies of the hydrogen bond. These bonds are due to sharing a proton by two electronegative atoms like oxygen. They are much weaker—only 4.5 Kcal. per g. mole in cellulose—than the electron sharing homopolar bonds but their significance to polymer structures and properties cannot be overemphasized. Probably the evolution of the whole of living matter in all of its infinite variations on this planet was controlled and directed by this bond to at least as great an extent as by any other single factor. Its origin may be studied in Pauling's book (*3*) while details of its physical and chemical manifestations may be followed in the excellent review by Davies (*4*) and in the symposium on the hydrogen bond held by The Royal Institute of Chemistry (*5*). The strength of this bond varies from less than 1 Kcal. per g. mole up to some 10 Kcal. per g. mole depending on the nature of the atoms which the hydrogen is bridging and the presence of other atoms or groups nearby. Similarly the equilibrium distances between the atoms which are bonded by the intermediate hydrogen vary from about 2.4 to 3.5 A.; the smaller distances are associated with larger energies. In cellulose the mean energy value is 4.5 Kcal. per mole (*6*) and the distance between the centers of the oxygen atoms of the O- - - - -H-O structure is approximately 2.7 A. (*7*).

The third and weakest attractive energies are the ubiquitous van der Waals' energies which bind all types of molecules together. They are rarely more than 1 or 2 Kcal. per g. mole and they act at distances of 3 to 5 A. They contribute to the energy of cohesion even when such "inert" groups as CH_2 and CH_3 come together. Thus, they contribute to the cohesion between elements of the cellulose chain molecules which come sufficiently near each other even when all other types of bonds are absent.

This is a very brief but, it is hoped, an adequate review of pertinent facts concerning the types of forces and energies which can contribute to the welding of the elements which ultimately form paper together. It is now necessary to present an equally brief but adequate review of these elements themselves. It may then be hoped to synthesize the two sets of facts into a verifiable theory of cohesion at the molecular level.

It is an interesting fact that if one avoided certain highly specific areas of special characteristics—e.g., pits in fiber walls—then one could take a section of a paper sheet and prepare photomicrographs with magnifications rising from say 10× through 100×, 1000×, 10,000×, and even 100,000× and produce five pictures which will look, in general, so very much alike that it is essential to label each picture by its magnification factor for identification purposes. Insofar as the optical and electron microscopes have gone they have revealed a continuous repetition of essentially the same pattern. This is a pattern of very long, slender fibrilar elements occasionally grouped together in parallel, well-ordered, and coherent strands of fibers, but interspersed by regions where individual elements cross from one ordered region to another in a random direction. The electron microscope has reached such a high resolution, that it is very tempting to extrapolate this picture (which is still essentially the same when the

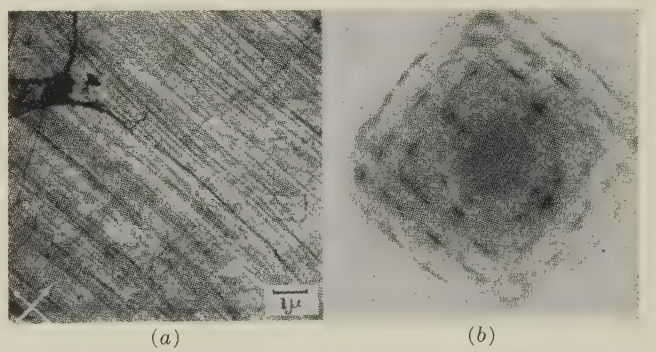


Fig. 2. (a) Electron micrograph and (b) electron diffraction pattern of Valonia microfibril cooled to −40°C., taken by Boersch-le Poole's method

ordered bundles are primary crystallites of only 50 A. wide by 50 A. thick and, say, 300 to 1000 A. long) to molecular dimensions of 5 to 10 A. However, it is not necessary to do so. Direct evidence from x-ray and electron diffraction fully confirms that at the molecular level we have essentially the same picture. Regions of strictly ordered, crystalline patterns with cellulose molecules being side by side are interspersed by regions of disorder and amorphous chaos. Figure 2

illustrates the jump from photomicrography to diffraction patterns where the same area is viewed by the two techniques described in an important paper by Honjo and Watanabe (*8*). These workers have

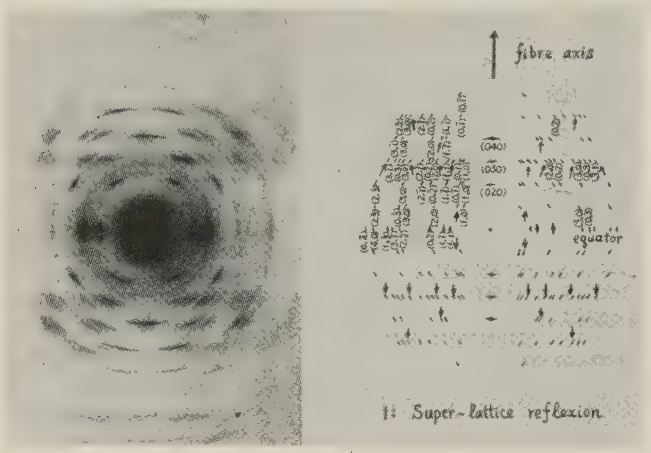


Fig. 3. Electron diffraction pattern of Valonia microfibril cooled to −100°C., taken by Hillier's method

shown that the basic structural unit for crystalline cellulose is a monoclinic cell having sides $a = 8.39$ A., $b = 10.58$ A., and $c = 7.94$ A. with $\beta = 82°$ (not greatly different from the familiar Meyer-Misch cell of 8.35 A. × 10.3 A. × 7.9 A., $\beta = 84°$). However, by cooling their specimen while irradiating it Honjo and Watanabe were able to throw a great deal more light on the subject. In Fig. 3, taken from the same paper, no less than 400 reflection spots appear in contrast with older pictures showing only a few. As a result, a superlattice of a and c periods, twice as long as the Meyer-Misch cell, becomes apparent. This means that the superlattice has dimensions of 16.8 A. by 15.9 A. Since the width and thickness of the crystallite at the highest resolution are only some 50 A. each, it follows that we are dealing with only 3 by 3 superlattice units side by side when we look at a crystallite. While this fact is not proof that the crystallite is a *perfect* crystal, I shall take it to be a strong *prima facie* case that in the model I wish to use later the crystalline portion of cellulose is indeed composed of perfect crystals with the main attractive energy binding the lattice together being the hydrogen bond.

This point is important. Perfect crystals—i.e., free from dislocations—are extremely strong. In a theoretical paper which is highly illuminating. Longuet-Higgins (*9*) shows that thermodynamically, the hydrogen bond is peculiarly suited for a number of such bonds to act cooperatively. In other words, a large number will act together. He further shows that even if they do not all break together but sequentially—as in a zip-fastener—they require an energy of activation equal to $n(kT + \epsilon)$, where n is the number of bonds involved, k is Boltzmann's constant, T is the absolute temperature, and $(-\epsilon)$ is the binding energy of a single bond. Thus, a perfect crystal will require a very large energy to strip even one chain bound to the rest by hydrogen bonds, since the length of the crystallite of say 300 to 1000 A. will involve n values exceeding 100. Thus, for all practical purposes, we may take the crystallites as rodlets of approximately 50 × 50 × 1000 cu. A. which pass through all the mechanical and most of the chemical processes of papermaking without change. Similarly, they will pass through all later mechanical operations in converting machinery, in use, and in testing without failure.

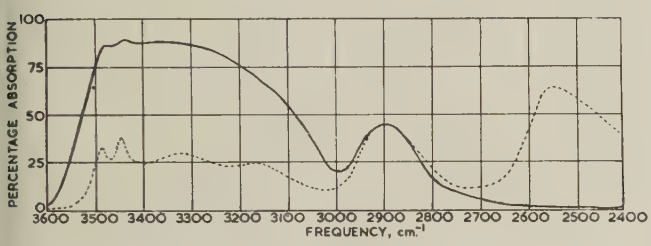
It remains to look at the amorphous regions connecting and cementing the crystallites together. It is an unfortunate circumstance that while the amorphous region is the seat for most of the important physical and chemical processes involving cellulose in papermaking, it is the very region which is not accessible to direct viewing by x-ray and electron-diffraction methods. All the same there are certain basic facts which tell us a great deal about the structure of this region. The first of these concerns its density. P. H. Hermans (*10*) discusses the density of cellulose at great length and finds that a reasonable value for the density of the amorphous region—i.e., one which accords with other facts—is one which is 6% less than that of the crystalline region. Thus, if a mass of cellulose occupies a cube of 1 cm. side when it is in the crystalline region it will occupy a cube of only 1.02 cm. side if it is completely amorphous. This is a significant fact. It indicates that the amorphous region, while it is "in disorder," is not without certain strictly controlling restraints. This hypothesis is similar to one advanced by Bernal regarding the structure of liquids and published only this year (*11*); indeed it has been inspired by a study of his work. In a tentative and mostly qualitative theory of liquid structure, where disorder is the rule and long range order is absent, Bernal found that the packing of molecules in irregular patterns exhibited certain very strong tendencies suggestive that they were following laws of an, as yet, unformulated science which he termed "statistical geometry." By empirically attempting to discover some of the general laws of irregular packing he found that irregular arrangements always occupied a volume of about 10% greater than dense packing. He formulates the following generalization: "There is an absolute impossibility of forming a homogeneous assembly of points of volume intermediate between those of long range order and closest packed disorder."

It may be objected that in liquids, near the melting point, the structure which Bernal postulated was that of "homogeneous, coherent, and essentially irregular assemblages of molecules containing no crystalline regions or holes large enough to admit another molecule" whereas here we are dealing with long segments of fibers in a solid state. It is my thesis that in fact the amorphous region fulfills the conditions as postulated above for liquids. Besides the evidence of density already quoted we may quote two further important observations. In a recent paper by P. H. Hermans (*12*) and his colleagues the amount of voids which contribute to small angle x-ray scattering in cellulose was measured. It was found that the total void was 3.5% by volume of which the void with dimensions less than 300 to 400 A. occupied about 0.7% of the volume. Since we already accept the crystallite as perfect, it follows that these small voids exist in the amorphous region. In other words the amorphous region is well packed except for some 1.4% of its own volume (assuming amorphous to crystalline ratio of 1:1). If some of the voids existed in the crystallite, the amorphous region would have even less than 1.4%. The second piece of evidence is afforded by the work of

Marrinan and Mann (*7*). In Fig. 4, taken from their work, it will be seen that there is no evidence that free hydroxyl groups exist; these would absorb around 3600 cm.$^{-1}$. Thus, the amorphous region, like the crystalline region, has all its OH groups joined by hydrogen bonds.

The picture which emerges from all this discussion is a reiteration of Bernal's dictum in another form: there is a sharp division of order and disorder in cellulose. The crystallites are perfect crystals which exhibit long-range order; the amorphous region is liquid like in its disorder. It exhibits no long-range order whatever but only the short-range order of immediate neighbors. This means that we can treat it as homogeneous; a very important fact. It does not mean that there is absolutely "no order" in the amorphous region for, indeed, liquids exhibit short-range order within the immediate neighborhood of a molecule. To put these statements quantitatively one may say:

1. Crystallites will exhibit cooperative phenomena due to their hydrogen-bonding with the number of cooperating units usually exceeding a hundred.



(*a*) —— Viscose film before deuteration
(*b*) ..... Viscose film deuterated for 4 hrs.

Table I

	Frequency, cm.$^{-1}$				
Cellotetraose	3485	3444	3376, 3305, 3253		3133
Cellopentaose	3484	3443	3323		3162
Cellulose	3484	3444	3322		3163

Fig. 4

2. Amorphous regions will exhibit cooperative phenomena due to their hydrogen-bonding with the number of cooperating units being equal to the coordination number of close packing which is usually less than 12 to 14.

We will close this section of marshalling our facts and theories by reference to an observation made in a previous study (*13*). In studying the breakdown of bonds in cellulose either by water or by relaxation of tensile stress at constant strain it was found that on the average six bonds broke down "simultaneously" at 65% R.H.; the maximum number was of the order of 12 to 14.

MODEL FOR QUANTITATIVE STUDIES

We will assume a simplified structure. It is composed of pure cellulose; there are no side chains, nor substitutions of OH groups by other types which give ionic linkages, or interconnecting molecules of different compositions. Thus, the only cohesive energies which will come into play between molecules are (1) H-bonds and (2) van der Waals'. To simplify our analysis further, we will work, at least at first, with a structure in which the van der Waals' contribution to the cohesion of molecular segments is negligible.

In a previous study (*13*), it was shown that if all possible H-bonds in the amorphous region were made available for straining, a cellulosic sheet would attain a Young's modulus $E = 10^{11}$ dynes per sq. cm. and that E increased with the cube root of the number of such bonds. Thus, if E is approximately 2×10^{10} dynes per sq. cm. this fact means only 1% of the total number of possible bonds are, in fact, taking part. We will, therefore, confine our studies—at the beginning, at least—to papers with $2 \times 10^{10} < E < 10 \times 10^{10}$. Fortunately, this covers practically the whole range of paper qualities.

Within this region, pure cellulose will consist of perfect crystallites embedded in a mass of homogeneous, irregularly packed amorphous region. The crystallites will act as nonyielding solid rodlets serving only to transmit stress. Strain energy will be taken up entirely in the amorphous region, and for paper with E exceeding 2×10^{10} dynes per sq. cm. we assume, at first, that this strain energy will be taken up entirely by the hydrogen bonds. The postulate of homogeneity implies that if, in any portion, we find n H-bonds per cu. cm. oriented toward a particular direction, then in every other portion of the sheet the same number will be found.

The mean value of the hydrogen bond energy is 4.5 Kcal. per g. mole (*6*). The energy per bond is therefore $(-\epsilon) = 3.12 \times 10^{-13}$ ergs. As Fig. 4 shows, however, there must be a range of values around this mean. We shall assume that the frequency distribution of the various values of the energy around this mean follows the normal error law with a standard deviation of σ ergs per bond. There is no known measured value for σ or (σ/ϵ). A study of Marrinan and Mann's work (*7*) as well as of others (*4*) would suggest that a range from 2.5 to 7 Kcal. per g. mole is not unreasonable for cellulose insofar as infrared spectroscopy evidence can be used for the estimate—i.e., some 100% of the mean value. Since spectroscopic data will detect minimum concentrations of, say, 0.1 to 1% this is equivalent to the range observed in a sample consisting of between 1000 and 100 individuals. The range in such samples is between 5 σ and 6 σ. Thus (σ/ϵ) is probably not less than 0.15 and not more than 0.20.

THEORY OF COHESIVE STRENGTH OF CELLULOSE SHEET

Consider a chain of m links each requiring ϵ units of energy to break, subjected to tensile stress. The total rupture energy (R.E.), which it will absorb before it fails is $m\epsilon$. If one of these links failed when it only absorbed $(\eta/100)\epsilon$ units of energy, with η being a percentage value less than 100, then the total rupture energy of the chain, R.E., is $(\eta/100)$ $(m\epsilon)$. (If η is greater than 100%, R.E. remains equal to $m\epsilon$ without further gain.) If two or more links fail when they absorb only $\eta\epsilon$ each, R.E. will still equal $(\eta/100)$ $(m\epsilon)$ independently of the number of weak links. Finally, consider a chain the links of which have different energy values ϵ_i with ϵ_i distributed around the mean $\bar{\epsilon}$, so that for each link we may put $\epsilon_i = (\bar{\epsilon} \pm t_i\sigma)$ with t_i being some multiple (not necessarily an integer) of σ, the standard deviation. Such a chain will fail when the weakest link of $\epsilon_i = (\bar{\epsilon}\text{-}t_{\max.}\ \sigma)$ fails. R.E. will then equal $m\epsilon_i$ or

$$\text{R.E.} = (\eta/100)(m\bar{\epsilon}) = m\epsilon_i = m(\bar{\epsilon} - t_{\max.}\,\sigma) \qquad (1)$$

This introduces the criterion, η, which measures the "efficiency of loading" the chain. Thus

$$\eta,\ \% = 100(\text{R.E.}/m\bar{\epsilon}) = 100[1 - t_{\max.}\,(\sigma/\bar{\epsilon})] \qquad (2)$$

A cube of 1 cm. side possessing a total of n bonds all in the direction of the stress vector and distributed uniformly throughout its space may be considered as consisting of $n^{2/3}$ chains in parallel, each chain consisting of $n^{1/3}$ links. If n is very large, then each chain may be taken as representative of all others. Thus if equation (1) applies to each chain, then for the whole cube

$$\begin{aligned}\eta &= 100(\text{R.E.}/n^{2/3}\ n^{1/3}\bar{\epsilon}) \\ &= 100(\text{R.E.}/n\bar{\epsilon}) \\ &= 100[1 - t_{\max.}(\sigma/\bar{\epsilon})]\end{aligned} \qquad (2)$$

In other words equation (2) still applies with the substitution of n, the total number of bonds in the direction of stress per unit volume, for m the total number of bonds per chain.

If the frequency distritution for ϵ_i around $\bar{\epsilon}$ is Gaussian, then the relative probability of $t_{\max.}$ occurring once in a chain of $m = n^{1/3}$ links is $(1/n^{1/3})$ and is also given by

$$(1/n^{1/3}) = (1/\sqrt{2\pi})\exp(-t^2_{\max.}/2) \qquad (3)$$

This gives

$$\eta = 100\ \text{R.E.}/n\bar{\epsilon} = 100\{1 - [\sqrt{2\ln(n^{1/3}/\sqrt{2\pi})}](\sigma/\bar{\epsilon})\}$$

For a test piece S cm. long, the probability of finding a still weaker link than in a 1-cm. long sample is increased and

$$\eta = 100\ \text{R.E.}/n\bar{\epsilon} = 100\{1 - [\sqrt{2\ln(Sn^{1/3}/\sqrt{2\pi})}](\sigma/\bar{\epsilon})\} \qquad (4)$$

In previous studies on the contribution of the hydrogen bond to the mechanical properties of cellulose sheets (*13*) it was deduced that

$$n = (E^3/3.43 \times 10^{11}) \qquad (5)$$

where E = Young's modulus.

If it is assumed that n in equation (4) is identical with that of equation (5), then we have two equations for η:

$$\begin{aligned}\eta &= 100\ \text{R.E.}/n\bar{\epsilon} \\ &= (1.1 \times 10^{26})(\text{R.E.}/E^3)\end{aligned} \qquad (6)$$

and

$$\begin{aligned}\eta &= 100\ \{1 - [\sqrt{2\ln(Sn^{1/3}/\sqrt{2\pi})}](\sigma/\bar{\epsilon})\} \\ &= 100\ \{1 - [\sqrt{2\ln(SE/7 \times 10^3\sqrt{2\pi})}](\sigma/\bar{\epsilon})\}\end{aligned} \qquad (7)$$

It remains to be added that this derivation assumes macro-and microhomogeneity. In paper, "formation" introduces a factor unaccounted for by this theory. Therefore, one would expect this theory to work with handmade laboratory sheets which are macroscopically homogeneous better than with machine-made anisotropic macroscopically heterogeneous papers.

The microhomogeneity assumed ignores the effects of molecular, crystallite and fiber lengths which tend to bridge across weak links. All three tend to act in a similar way, namely, to reduce the weakening effects of S, the sample length. If the molecular, crystallite and fiber lengths are denoted by M, C, and F, respectively, their effects may be introduced into equations (4) and (7) by using an effective sample length S_E instead of S where

$$S_E = S[1 - f_1(M/S)][1 - f_2(C/S)][1 - f_3(F/S)] \qquad (8)$$

There is no information available at present regarding the functions f_1, f_2, and f_3. It may be expected, however, that all three will be finite corrective terms for small values of (M/S), (C/S), and (F/S) and increase asymptotically to another set of finite values as the three ratios approach unity—i.e., as the sample length decreases to values corresponding to a fiber length [0(1 mm.)] or molecular length [$0(10^{-3}$ mm.)]. At present it is necessary to ignore these effects in this first approximation to a quantitative evaluation of $(\sigma\bar{\epsilon})$. When data on the variation of R.E. with M, C and F become available it will be possible to evaluate the three functions and refine the theory. Thus in the present paper equation (7) will be used and S_E will be arbitrarily assumed equal to S; this is not only necessary but is probably acceptable since (1) S is large (10 cm) compared to M, C, and F (10^{-4}, 10^{-5}, and 10^{-1} cm., respectively); (2) S remains constant in all tests; and (3) the results which will be studied probably have nearly the same values of M, C, and F and hence the same f_1, f_2, and f_3.

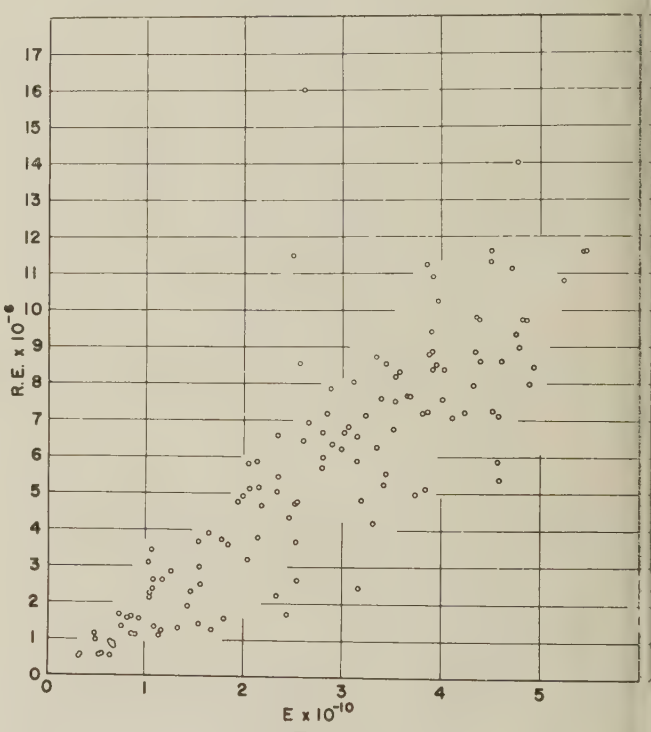


Fig. 5

AGREEMENT BETWEEN THEORY AND OBSERVATION

Higgins and his colleagues have published a large number of values of R.E. and E for sheets made from pulp beaten to different degrees as well as chemically treated in order to substitute the OH groups in the amorphous region to different degrees by hydrophobic groups. Their results are shown on Fig. 5.* That R.E. is connected with E is as obvious as the fact that the presence of at least one other factor is causing a very wide scatter.

* The values for R.E. in this paper are given in units of energy per unit volume of sample—i.e., in ergs per cubic centimeter. Higgins' original results are in ergs for the whole sample.

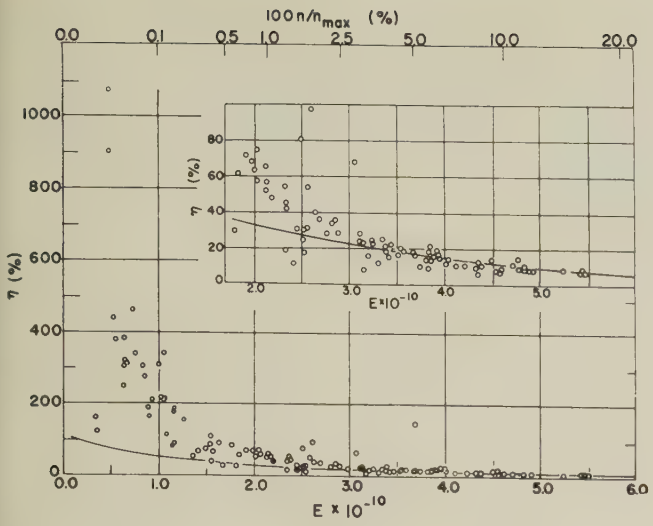


Fig. 6

Figure 6 shows a plot of $\eta\%$, calculated by means of equation (6) versus $E \times 10^{-10}$. The insert expands the η scale for points with $E \times 10^{-10} > 2.0$. On the top scale is shown $(100\ n/n_{\max.})\%$, i.e., the estimated number of hydrogen bonds taking part in the straining operation as a percentage of the total possible. Thus, the inset is for values of $(100\ n/n_{\max.})$ exceeding 1%. The solid lines shown in both the full graph and the inset are calculated by equation (7) for values of (σ/ϵ) of 0.132—i.e., a standard deviation of bond energy of 13.2% of the mean. It appears that there is reasonable agreement between the theory proposed on the basis of the simplified model and observation.

REFINEMENT OF THE MODEL

In the theory the contribution of the van der Waals' energy was ignored. These contributions may be estimated from results of low value of E when they become commensurate with the contribution of the hydrogen bond itself. If the difference in η shown in Fig. 6 between the solid curve and the mean of the experimental points for $E < 2 \times 10^{10}$ is attributed to van der Waals' energy, then the total η may be partitioned between that due to H-bonds (taken as represented by the solid curve) and that due to van der Waals' as the remainder. From η so calculated the portion of R.E. due to van der Waals' forces is calculated and subtracted from the total to yield the portion due to H-bonds.

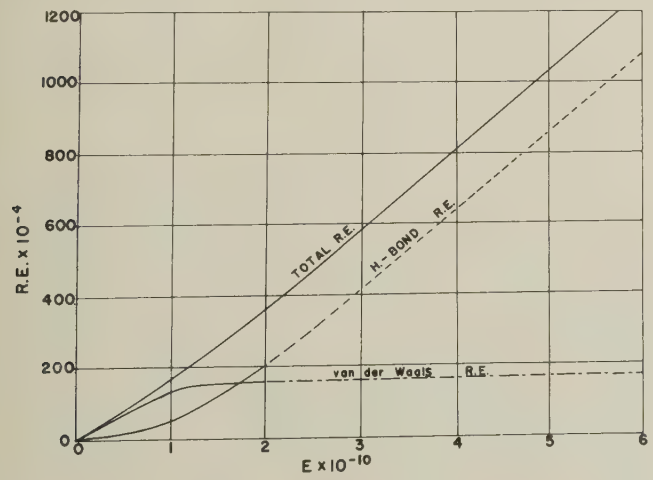


Fig. 7

In Fig. 7 is shown the partition of total R.E. into H-bond R.E. and van der Waals' R.E. (Strictly, these calculations should be by reiteration with successively closer estimates of (σ/ϵ)—probably nearer 0.145 than 0.132. In other words, the solid line on Fig. 6 should be drawn at a lower level to allow for van der Waals' R.E. of about 140,000 for high E values. The accuracies of the results as well as the theory, however, do not warrant such refinements.)

It will be seen that for very weak paper sheets—produced either from unbeaten pulp or from pulp the OH groups of which had been substituted by hydrophobic groups (and probably for sheets made from suspension in benzene although these have not been studied here)—the van der Waals' forces predominate. These are probably the source of so-called "mechanical friction forces between fibers" or "entanglements" frequently invoked by students of sheet properties. As hydrogen bonds begin to form between fibrils, the cohesive energy they impart to the sheet increases, at first slowly and then rapidly. Two trends however should be noted: (1) the van der Waals' energy tends to assume a constant maximum value, shown by the dotted line since their exact magnitude is unknown. This is not inconsiderable; even the strongest sheets made in these studies probably owe some 20 to 25% of their rupture energy to van der Waals' energy. (2) As the number of hydrogen bonds increases, the chances of meeting still weaker bonds—i.e., t of still higher values in $\epsilon_i = [\bar{\epsilon} - t(\sigma/\bar{\epsilon})]$—increases. Thus the actual efficiency of loading, η, drops from an average value of 35% for very weak sheets to values approaching 7% for very strong sheets. If the reiteration indicated above for obtaining a closer estimate of (σ/ϵ) and of η were carried out, η would probably drop from 25% for weak papers down to 4 to 5% for strong sheets.

CONCLUSION

The cohesive strength of cellulosic sheets follows the old adage of "a chain is as strong as its weakest link" but with the further paradoxical refinement: "the 'stronger' the chain, the weaker is its weakest link"

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Dimensional Stabilization of Paper by Crosslinking with Formaldehyde

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Dimensional stability is imparted to paper by crosslinking with formaldehyde in the vapor phase. The reaction is catalyzed by volatile acids and acidic salts. Studies of the effects of formaldehyde and catalyst concentration, and of reaction temperature and time on the dimensional stability and on the various dry and wet strength properties show that reasonably good dry strengths and greatly increased wet strengths are obtained up to reductions in swelling of 40%. Further reaction to attain higher degrees of dimensional stabilization, results in a considerable loss in some dry strength properties due to embrittlement of the paper. Only in cases where a significant loss in these dry strength properties is unimportant can the stabilization be safely carried to reductions in swelling of 60% or more.

In the previous paper by the authors (*1*) it was shown that volatile acids and acidic salts and also sodium hydroxide catalyze the dimensional stabilization of paper by heat. Reductions in swelling as great as 60% were obtained. Acid catalysts caused the greatest loss in bursting and tearing strengths and in folding endurance. The acidic salts caused considerably less loss in these three properties and small amounts of sodium hydroxide and no catalyst were still better, the low concentrations of sodium hydroxide actually improving the folding endurance.

Stamm (*2*) has shown that, if paper containing a suitable catalyst such as zinc chloride, is heated in an atmosphere of formaldehyde vapor, dimensional stability develops more rapidly as a result of crosslinking. The rate of the crosslinking reaction was affected by the nature and amount of catalyst present, and by the availability of the formaldehyde, but not by the moisture content of the paper at which the reaction takes place, i.e., below 70%, R.H. The dry strength of the paper that had been dimensionally stabilized by the crosslinking reaction, seemed to be reduced only because of embrittlement. Even though reductions in swelling as great as 80% were attained, it was considered practicable to limit it to less than 60% so as to avoid excessive embrittlement. Wet strength values comparable with those obtained with 10% of phenol-formaldehyde resin in the paper, were obtained by crosslinking with as little as 0.5% of formaldehyde. It was concluded that, though dimensional stabilization by heat treatment should be limited to applications where considerable embrittlement is permissible (*1*, *2*), formaldehyde crosslinking should be more generally applicable, because it embrittles the paper to a lesser degree. The crosslinking reaction has been studied further with respect to reactant, catalyst, time, and temperature, with the objective of reducing the embrittling potential caused by the treatment.

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MATERIALS AND PROCEDURE

The majority of the treatments and measurements were performed on a kraft paper of 60 lb. per ream (25 × 40—500) made without size or filler, on the Forest Products Laboratory experimental fourdrinier machine from a commercial spruce-fir unbleached sulphate pulp, which had been beaten to a freeness of 500 ml. (Canadian Standard). Some limited tests were also performed on a paperboard and paper made from a pine-eucalypt kraft furnish, having a high eucalypt content. The papers and board were all cut into 10.5 by 8-in. sheets. To provide ample material for subsequent tests, five such sheets selected at random constituted a sample.

For the majority of treatments, both catalyst and reactant were used in the vapor phase. Therefore, treatments were performed in a relatively gas-tight, stainless steel box of 16 liters capacity, and of sufficient height to permit the sheets to be suspended lengthwise within it. A small hole was punched in each sheet near the middle of one end for threading it onto a stainless steel rod. Additional sheets, bearing thermocouples, were interleaved with those undergoing treatment so as to provide a means of measuring temperatures and their variation, and thus to assist in temperature control. Spacers cut from rubber tubing were slid over the rod between the sheets to hold them apart. The rod and sheets were suspended from the inside of the box cover. The box was closed with stiff spring clips securing the rubber gasketed cover. The box was heated in an oven equipped with forced air circulation.

For those treatments in which the paper was impregnated with a salt catalyst, the catalyst was introduced by immersing the paper in the salt solution at the same concentration as the final salt content desired in the paper. The procedure for this impregnation has been more fully described (*1*).

When the catalyst was an acid vapor, the acid solution (concentrated or slightly diluted with water) was admitted to the reaction box by means of a feed tube passing through one end and delivering to a small glass evaporating dish located centrally at the bottom of the box. This admission took place after the sheets within the box had reached the designated treating temperature. The small quantity of acid solution added vaporized almost instantly so the time of this admission was designated as the reaction starting time.

Except in a few experiments, the reactant formaldehyde was made available in the vapor phase by placing

the required quantity of solid paraformaldehyde in two evaporating dishes inside the box while the sheets were being suspended from the reaction box lid. A constant vapor pressure of formaldehyde was established over the paraformaldehyde by the time the sheets had reached the designated treating temperature.

For those few experiments in which neither catalyst nor reactant was used in the vapor phase, sheets were impregnated with a solution containing alum and formalin, according to the procedure already described. These sheets were dried to equilibrium moisture content at 65% R.H. and 26.7°C., before heat treatment.

The box was placed in the oven which had been set a few degrees above the operating temperature. When the sheets had reached this temperature, the oven was reset to hold the temperature constant. In the vapor phase treatments, the oven was temporarily reset slightly below the designated temperature to counteract the sudden observed rise in temperature within the box after the acid catalyst had been admitted. Later, the oven was again reset to hold the designated temperature within ±2°C. throughout the treating period. At the termination of the reaction time, the box was taken immediately from the oven, and by virtue of the spring clips, quickly opened. Thus, the reaction time could be accurately terminated.

The treated sheets were conditioned to equilibrium moisture content at 65% R.H. and 26.7°C. Strips of the treated paper and of untreated controls, about 17 cm. long in the cross-machine direction and 1.5 cm. wide, were cut, one from each sheet, and soaked in water overnight to relieve drying stresses. They were then dried without restraint to equilibrium moisture content at 30% R.H. and 26.7°C. Their lengths were measured under a magnifying glass with a steel rule to within ±0.1 mm. The strips were then soaked in water overnight and again measured. The dimensional stabilization was calculated in terms of per cent reduction in swelling, i.e., (swelling of control − swelling of treated paper/swelling of control) × 100.

In addition to swelling tests, the treated paper and untreated controls were subjected to TAPPI Standard tests for basis weight, thickness, density, bursting and tearing strengths, folding endurance, dry and wet tensile strength, and dry and wet ring compression. Those tests which are subject to a directional effect, were made in the cross-machine direction only. Creased tensile tests were attempted but they did not always result in failure at the crease; hence reliable values were not obtained, and this test was subsequently abandoned.

ACID-CATALYZED CROSSLINKING

Reactant and Catalyst Concentrations

A series of treatments and measurements was made to determine whether there would be optimum concentrations for the reactant formaldehyde and for the acid catalyst with respect both to rate of reaction and degree of dimensional stabilization and to dry and wet paper strengths. Two acids, viz. hydrochloric and formic, were studied.

Formaldehyde as Reactant. With hydrochloric acid serving as catalyst at an arbitrarily fixed concentration of 12.5 mg. per liter of box capacity and with treating temperature and time constant at 120°C. and 60 min., respectively, treatments were made with the formaldehyde available in concentrations varying from 25 to 625 mg. per liter of box capacity. Subsequent measurements showed that there was little change in dimensional stabilization once the formaldehyde concentration had exceeded 100 mg. per liter, or in paper strength above 200 mg. per liter. The optimum concentration was, therefore, presumed to lie between these two, and in the majority of cases to be discussed, a concentration of 200 mg. per liter was made available.

Hydrochloric Acid as Catalyst. With formaldehyde available at a concentration of 100 mg. per liter and with treating temperature and time constant as above-mentioned, treatments were made with the concentration of available hydrochloric acid varying from 2.5 to 40 mg. per liter. Measurements for this series showed that the optimum concentration was approximately 12.5 mg. per liter. At higher concentrations, embrittlement of the paper was intensified as dimensional stabilization increased.

Formic Acid as Catalyst. A similar series of treatments with formic acid serving as catalyst at a concentration range from 15 to 140 mg. per liter of box capacity, showed that dimensional stabilization increased roughly linearly with the square root of formic acid concentration. Wet tensile and wet ring compression, which increased considerably with increasing dimensional stabilization, also increased linearly with an increase in the square root of formic acid concentration. On the other hand, tearing resistance decreased linearly but other dry properties were not seriously affected. Consequently, with no revealed optimum, the formic acid concentration would depend on the degree of dimensional stabilization sought, and, conversely, on

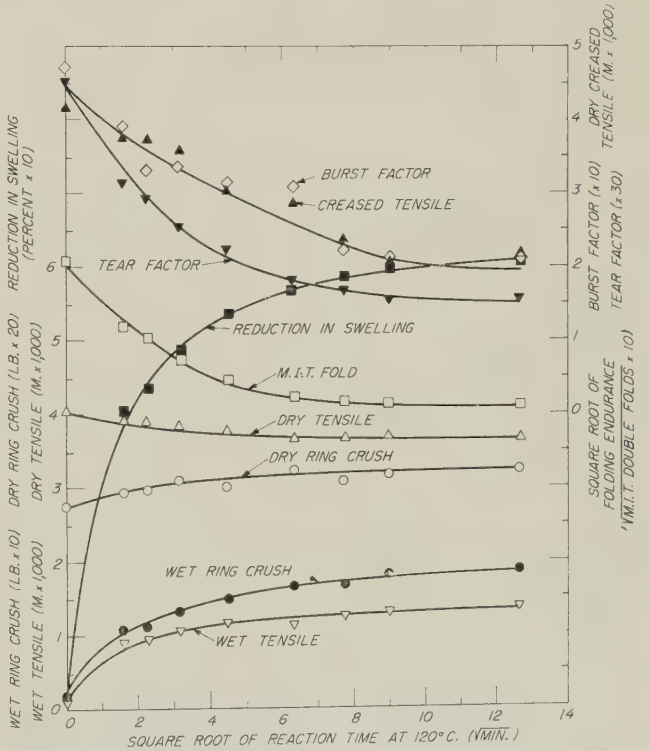
REDUCTION IN SWELLING (PERCENT × 10)
DRY RING CRUSH (LB. × 20)
DRY TENSILE (M. × 1,000)
WET RING CRUSH (LB. × 10)
WET TENSILE (M. × 1,000)
DRY CREASED TENSILE (M. × 1,000)
BURST FACTOR (× 10)
TEAR FACTOR (× 30)
SQUARE ROOT OF FOLDING ENDURANCE (√M.I.T. DOUBLE FOLDS × 10)
BURST FACTOR
CREASED TENSILE
TEAR FACTOR
REDUCTION IN SWELLING
M.I.T. FOLD
DRY TENSILE
DRY RING CRUSH
WET RING CRUSH
WET TENSILE
SQUARE ROOT OF REACTION TIME AT 120°C. (√MIN.)

Fig. 1. Reduction in swelling and the strength properties of unbleached kraft paper crosslinked with formaldehyde vapor versus the square root of the reaction time at 120°C. Chemical concentrations: paraformaldehyde, 100 mg. per liter of box capacity; hydrochloric acid, 12.5 mg. per liter of box capacity

the extent of embrittlement which could be accepted. It should be noted that, under the conditions of the above-mentioned treatment, reduction in swelling did not exceed the 40% level.

Moisture Concentration

For the sake of better control in adding the acid catalyst, it was necessary to dilute it slightly with water. Precautions were taken to ensure that, if the paper undergoing treatment absorbed all water vapor available in the treating box, its moisture content would not have exceeded 10 to 12%. Tests without and with water addition within these limits, have not revealed any significant effects which could be attributed to the moisture content at which the crosslinking reaction took place.

Reaction Time

Under constant conditions, which were arbitrarily chosen because the influence of reactant and catalyst concentrations was not fully known beforehand, a series of treatments for different times at 120°C. was made. The resulting test data for formaldehyde crosslinking with hydrochloric acid as catalyst are illustrated in Fig. 1 and lead to the following conclusions:

Dimensional Stabilization. The reduction in swelling increases rapidly with increase in reaction time below 20 min., after which it increases less rapidly and apparently exponentially. The lower part of the curve (Fig. 1), within the limits of proportionality, would conform with the activation energy value of 19,000 cal. per mole reported by Stamm (*2*). The upper part indicates that reduction in swelling much in excess of 60% could not be expected from the crosslinking treatment under the conditions used. The linear portion of the plot does not extend to as high a degree of reduction in swelling as in the data of Stamm (*2*). This is due most likely to the fact that he used a very large excess of paraformaldehyde over that needed for the reaction, whereas this was not true in these experiments.

Dry Strength Properties. With the exception of ring compression, the properties of the dry paper initially decline steeply and almost linearly with the increase in the square root of the reaction time and then assume a steady state, more or less exponentially. In the case of folding endurance, however, the level reached is approximately zero. This is ample evidence of embrittlement and strongly supports the other trends. On the other hand, ring compression is not adversely affected and, if anything, is slightly enhanced by the crosslinking treatment.

Wet Strength Properties. Wet tensile and wet ring compression are both improved manyfold by the crosslinking treatment, rather sharply during the initial stages, and eventually to levels of about one-quarter to one-third of the dry values.

Reaction Temperature

A series of treatments was made for various times at 100, 120, and 140°C., with a low concentration of hydrochloric acid of only 5 mg. per liter of box volume as a precautionary measure to limit embrittlement. Treatments at 80°C. were also attempted, but had to be abandoned when it was found that the solid paraformaldehyde would not readily vaporize at this temperature, and therefore, that the concentration of its vapor within the treatment box was small and unknown.

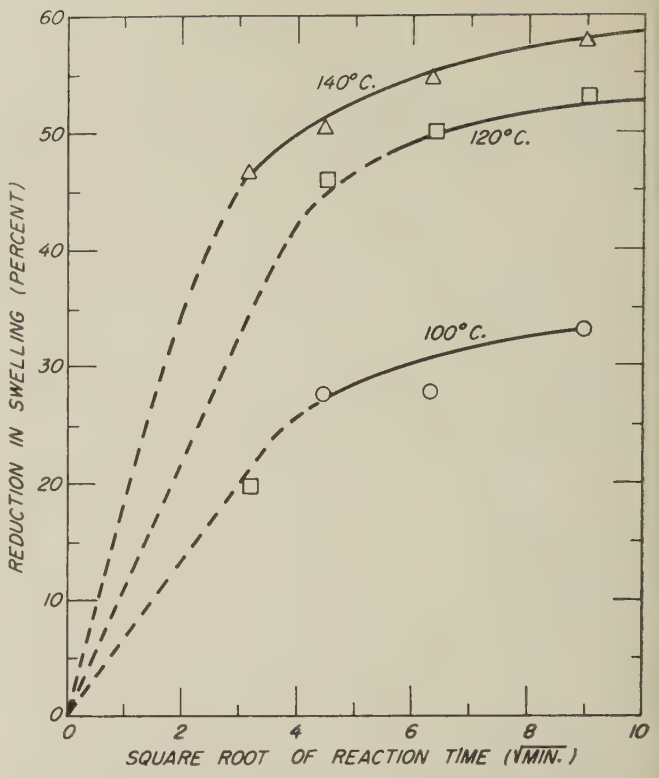

Fig. 2. Reduction in swelling of unbleached kraft paper crosslinked with formaldehyde vapor at three different temperatures versus the square root of the reaction time. Chemical concentrations: paraformaldehyde, 200 mg. per liter of box capacity; hydrochloric acid, 5 mg. per liter of box capacity; water, 325 mg. per liter of box capacity

The measurements on the treated paper have led to the following conclusions.

Dimensional Stabilization. The reduction in swelling increases linearly with an increase in the square root of reaction time, and then assumes a steady level, apparently exponentially (see Fig. 2). Those parts of the three curves illustrated in Fig. 2 by broken lines have been drawn to conform with the activation energy values reported by Stamm (*2*). It is noted that they connect up nicely with the initial observed points. The slope of the initial part of each curve increases with the increase in temperature, i.e., a designated level of dimensional stabilization is attained faster when the reaction temperature is increased. It appears that a temperature of 100°C. is too low if moderate-to-high dimensional stabilization is to be attained, and that, under the most favorable conditions applied at the higher temperatures, the maximum dimensional stabilization attained would be approximately 60%.

Strength Properties. Those properties which changed most with dimensional stabilization have been plotted in Fig. 3, the others having shown a small to negligible effect. This figure shows that the three properties illustrated are approximately linear functions of dimensional stabilization, the wet properties increasing, and folding endurance decreasing, with increase in reduction in swelling. It is to be noted that the regression of each property on dimensional stabilization may be represented by a single curve irrespective of temperature. Thus, strength property changes are not

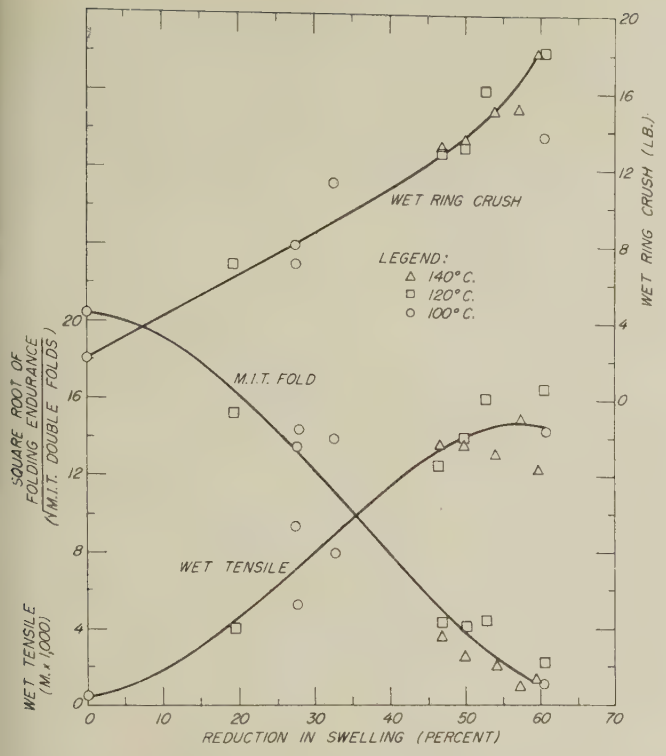

Fig. 3. Dry folding endurance, wet tensile and wet ring crush strength properties of unbleached kraft paper crosslinked with formaldehyde vapor at three different temperatures versus the reduction in swelling. Chemical concentrations were the same as those of Fig. 2

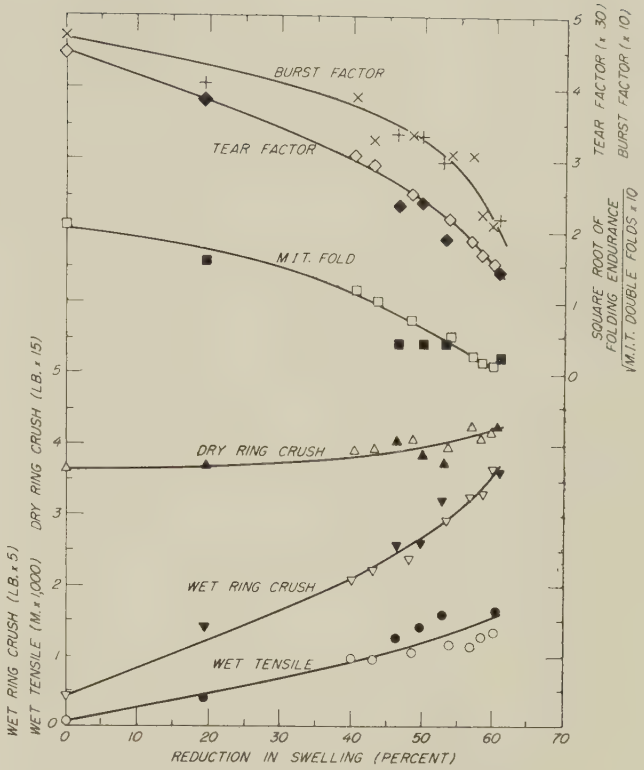
BURST FACTOR
TEAR FACTOR
M.I.T. FOLD
DRY RING CRUSH
WET RING CRUSH
WET TENSILE
WET RING CRUSH (LB. x 5)
DRY RING CRUSH (LB. x 15)
WET TENSILE (M. x 1,000)
SQUARE ROOT OF FOLDING ENDURANCE (√M.I.T. DOUBLE FOLDS x 10)
TEAR FACTOR (x 30)
BURST FACTOR (x 10)
REDUCTION IN SWELLING (PERCENT)

Fig. 4. Strength properties versus the reduction in swelling for unbleached kraft paper crosslinked with formaldehyde vapor at 120°C. Open symbols represent chemical concentrations of Fig. 1. Shaded symbols represent chemical concentrations of Fig. 2

directly dependent on reaction temperatures but are dependent on dimensional stabilization which, in turn, is influenced by both temperature and time.

Variation of Catalyst and Reactant Concentrations at a Given Temperature

During the course of the investigations just discussed, some dimensional stabilization and paper strength data were obtained with different catalyst and reactant concentrations, with or without added water vapor, but all at the one temperature, viz., 120°C. These data have been brought together and illustrated on Fig. 4. With the exception of wet tensile—for which there seems to be a significant deviation dependent on the vapor phase conditions at the higher values of reduction in swelling—the regression of a given property on dimensional stabilization may be represented by a single curve. It appears that strength properties are functions of the reduction in swelling attained, and that they do not vary with reactant or catalyst concentrations nor with the presence of water vapor in limited concentrations. This is similar to Stamm's finding with respect to wood wherein the relationship of abrasion resistance to dimensional stabilization was not affected by the kind or concentration of catalyst (*3*).

Formic Acid as the Crosslinking Catalyst

A series of treatments was made over various times at 120°C., with formaldehyde available at a concentration of 200 mg. per liter of box capacity, with water vapor present, and with formic acid at a concentration of 68 mg. per liter as catalyst. Subsequent measurements yielded data for reduction in swelling and strength properties which are illustrated on Fig. 5. The maximum reduction in swelling attained with formic acid as catalyst, was only 40%. It would have been necessary to treat for a substantially longer time or at a higher temperature to attain the level of dimensional stabilization realized with hydrochloric acid as catalyst. At the time that these treatments with formic acid were made, the emphasis was on moderate dimensional stabilization for the sake of limiting embrittlement, and the catalyst concentration and treatment time were restricted toward this end. Within the limits of dimensional stabilization common to both acid catalysts, it appears that, in substance, the data for both acids are complementary in showing that embrittlement is a function of dimensional stabilization and that the latter is independent of the nature of the acid catalyst for which there is an optimum concentration. Furthermore, the data show that improvement in wet strength is independent of the catalyst and also that the only remedy for restricting embrittlement is to aim at moderate levels of dimensional stabilization, i.e., not exceeding 40%. The last-mentioned conclusion confirms that of Stamm with respect to heat stabilization treatment (*2*).

Application to Papers of Hardwood Origin.—Treating conditions selected to attain a moderate degree of dimensional stabilization, i.e., not greater than 40%, were applied to three papers and one paperboard having a high hardwood pulp content. Three of these were made from eucalypt kraft pulp (63–78%) and *Pinus radiata* kraft pulp (37–22%) and the fourth was a water leaf paper made from a 100% Eastern United States hardwood neutral sulphite semichemical pulp. They responded somewhat differently to crosslinkingtre atment when formic acid served as the catalyst. Tearing resistance was the only property which was consistently

decreased. The fold varied from paper to paper. Dry tensile and ring compression were significantly enhanced. Under wet conditions these properties increased manyfold with increasing dimensional stabilization. Taking into consideration their variation in thickness and density, the only moderately varied response of these four papers to the same treatment conditions is not surprising. In general, the data showed that the crosslinking reaction is not specific with respect to the nature and composition of the paper furnish.

SALT-CATALYZED CROSSLINKING

Stamm (*3*) found that a number of mildly acidic salts will catalyze crosslinking of wood in the vapor phase reaction with formaldehyde. The rate of reaction is dependent on the nature and concentration of the catalyst. He also demonstrated for paper, that a liquid

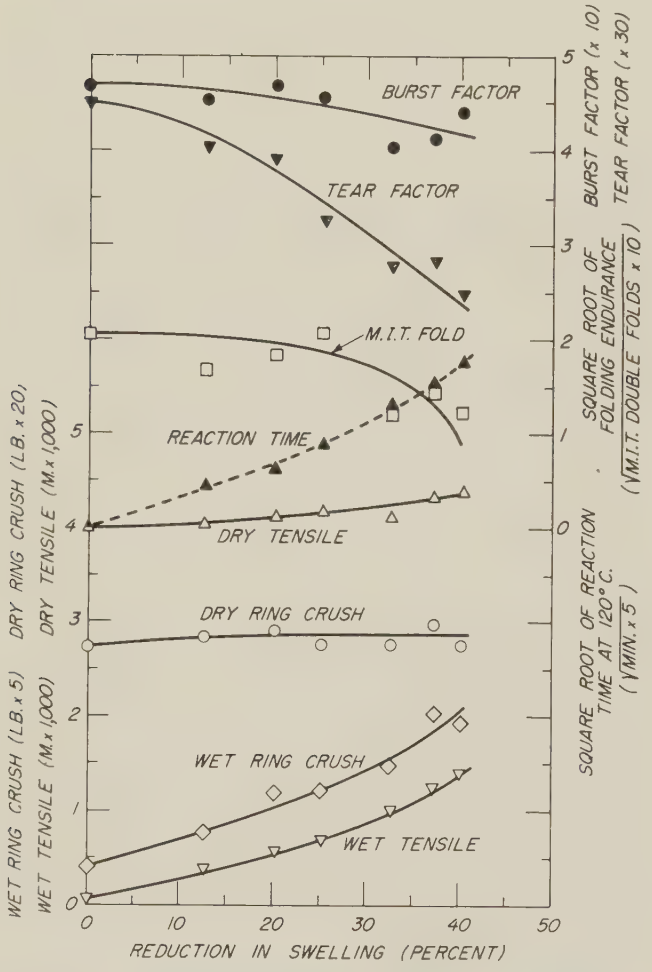
BURST FACTOR
TEAR FACTOR
M.I.T. FOLD
REACTION TIME
DRY TENSILE
DRY RING CRUSH
WET RING CRUSH
WET TENSILE
WET RING CRUSH (LB. x 5)
WET TENSILE (M x 1,000)
DRY RING CRUSH (LB. x 20)
DRY TENSILE (M x 1,000)
BURST FACTOR (x 10)
TEAR FACTOR (x 30)
SQUARE ROOT OF FOLDING ENDURANCE (√M.I.T. DOUBLE FOLDS x 10)
SQUARE ROOT OF REACTION TIME AT 120°C. (√MIN. x 5)
REDUCTION IN SWELLING (PERCENT)

Fig. 5. Strength properties and reaction time at 120°C. for unbleached kraft paper crosslinked with formaldehyde vapor versus the reduction in swelling. Chemical concentrations: paraformaldehyde, 200 mg. per liter of box capacity; formic acid, 68 mg. per liter of box capacity; water, 325 mg. per liter of box capacity

phase reaction with a formaldehyde solution containing a salt catalyst was quite effective so long as the paper was dried either before or during the heat treatment (*2*). In his investigations with paper he used zinc chloride almost exclusively as catalyst and, to a limited extent, sodium chloride.

Subsequent treatments have shown that alum is at least as effective as zinc chloride. Its concentration, however, appears to be a critical factor influencing the rate of reaction and the degree of embrittlement resulting from crosslinking. Paper containing different concentrations of alum as catalyst was crosslinked with

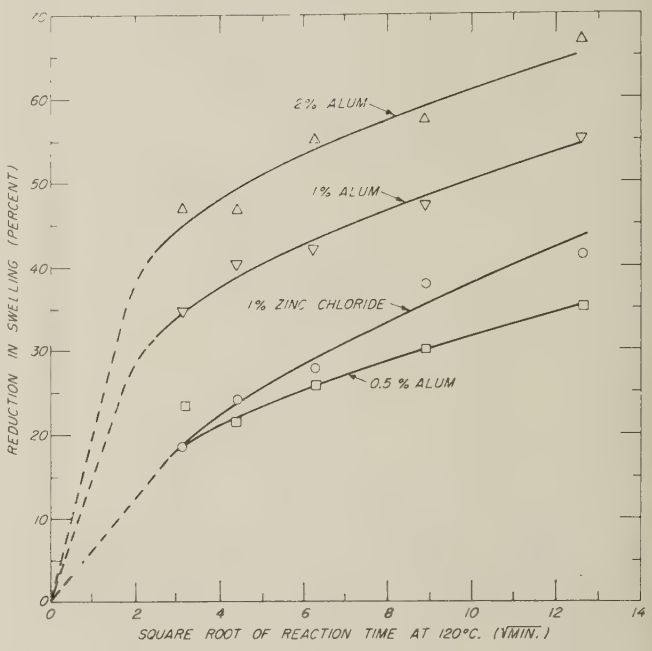

Fig. 6. Reduction in swelling of unbleached kraft paper crosslinked with formaldehyde vapor at 120°C. using two different salt catalysts versus the square root of the reaction time. Paraformaldehyde concentration, 200 mg. per liter of box capacity

formaldehyde vapor. For comparison and linking up with Stamm's observations, similar treatments were made on paper containing 1% $ZnCl_2$. Measurements on the treated paper given in Fig. 6 confirm Stamm's observations that the rate of the crosslinking reaction is dependent on the concentration and nature of the catalyst.

The relation of various strength properties to reduction in swelling is summarized on Fig. 7, where the regression of each property has been illustrated by fitting a single curve to all of the points, irrespective of the salt catalyst and its concentration. Because reduction in swelling greater than 55% was attained only when 2% alum served as catalyst, the parts of the curves above 55% are shown as broken lines. With the exception of dry tensile strength and dry ring compression, dry strength was degraded more rapidly and wet ring compression increased less rapidly with increasing dimensional stabilization, when the alum concentration was 2% than when lower concentrations were used. Except in the case of 2% alum, these curves clearly demonstrate that embrittlement (as indicated by the decline in dry strength) and wet strength improvement are essentially functions of dimensional stabilization. Embrittlement may be restricted only by aiming at moderate degrees of dimensional stabilization, viz., approximately 40%.

Comparison of Fig. 4, 5, and 7 definitely shows that embrittlement and wet strength development are essentially artefacts of crosslinking and that they are independent of the nature of the catalyst, whether this be

acid vapor or solid salt. They are also independent of the catalyst concentration provided it is confined within certain limits.

Continuous Liquid Phase Reaction

Attempts have been made to adapt liquid phase reaction with formaldehyde and alum to a continuous

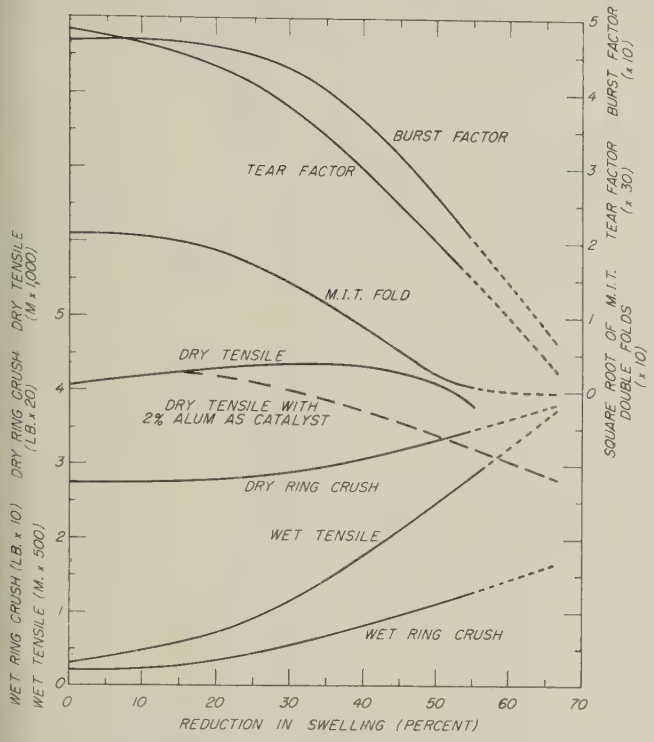
BURST FACTOR
TEAR FACTOR
M.I.T. FOLD
DRY TENSILE
DRY TENSILE WITH 2% ALUM AS CATALYST
DRY RING CRUSH
WET TENSILE
WET RING CRUSH
WET RING CRUSH (LB. x 10)
WET TENSILE (M. x 500)
DRY RING CRUSH (LB. x 20)
DRY TENSILE (M. x 1000)
SQUARE ROOT OF M.I.T. DOUBLE FOLDS (x 10)
TEAR FACTOR (x 30)
BURST FACTOR (x 10)
REDUCTION IN SWELLING (PERCENT)

Fig. 7. Strength properties of unbleached kraft paper crosslinked with formaldehyde vapor at 120°C. using salt catalysts, versus the reduction in swelling. Chemical concentrations: paraformaldehyde, 200 mg. per liter of box capacity; alum catalyst, 0.5, 1.0, and 2.0% of the dry weight of the paper; zinc chloride catalyst, 1.0% of the dry weight of the paper. Solid lines terminating in dashed lines represent average values for all of the catalysts. Dashed extensions and broken line represent values for 2% alum only. Data points omitted to avoid confusion

plant operation either on- or postmachine. As an on-machine experiment, the paper was given a kiss roll treatment at the size press with a solution of formalin and papermaker's alum and then redried. When the reels were later heated in an oven, thermocouples distributed within them revealed that there was less variation in temperature than was anticipated. Subsequent measurements also showed that dimensional stabilization took place fairly uniformly throughout each reel. Depending on the catalyst concentration, reaction temperature and time, reduction in swelling up to 56% was attained, but strength tests led to the usual conclusion that embrittlement increased with increasing dimensional stabilization, especially above 40%. Whereas wet tensile strength followed its familiar upward trend with dimensional stabilization, the data on wet ring compression were inconclusive. The importance of control of the alum concentration in relation to embrittlement was emphasized.

The postmachine liquid phase experiment was made by feeding the paper continuously through the Forest Products Laboratory's treater, normally used for phenolformaldehyde impregnation. After impregnation with a solution of formalin and alum, the wet paper was fed slowly through the drying tower of the unit where it was consecutively dried and heated so as to activate the crosslinking reaction. Although the slowest practicable speed was used, the restricted length of travel through the tower and the slow drying rate seriously curtailed the effective reaction time. Hence, the dimensional stabilization attained was very low—in fact, no greater than that attained without additional heating during the aforementioned on-machine impregnation experiment.

For continuous application, it appears that the catalyst should be included in the paper machine furnish and that the finished dry paper subsequently be passed through an atmosphere of formaldehyde vapor contained in a gas-tight, heated, reaction chamber at such a rate and temperature that crosslinking, commensurate with the desired dimensional stabilization, will take place.

Comparison of Formaldehyde Cross-Linking with Heat Treatment

Comparison of the effects of catalyzed heat treatment reported by Cohen, Stamm and Fahey (*1*) with those of cross-linking with formaldehyde reveals that heat treatment with a low concentration of sodium hydroxide (0.1%) gives the best results. This is strikingly demonstrated in summary by Table I in which the properties of treated sheets relative to those of the unheated untreated control sheets are given as ratios for two levels of dimensional stabilization and for three different treatments. Although the duration of catalyzed heat treatment was many times that of the crosslinking

Table I. Comparison of the Best Dimensional Stabilization Obtained by a Catalyzed Heat Treatment with That Obtained by a Formaldehyde Crosslinking Treatment

Stabilization treatment				Relative change in strength properties,[a]						
		Duration of heating at 120°C.				Folding	Tensile		Ring crush	
Type	Catalyst	Hr.	Min.	Tearing	Bursting	(MIT)	Dry	Wet	Dry	Wet
				Reduction in Swelling—40%						
Heat	Sodium hydroxide—0.1%	16	..	0.93	0.94	1.10	1.02	7.8	0.99	2.5
Formaldehyde	Alum—1.0%	...	25	0.67	0.77	0.20	1.07	16.1	1.15	4.0
crosslinking	Formic acid	1	26	0.53	0.88	0.025	1.10	24.7	1.06	5.0
				Reduction in Swelling—48%						
Heat	Sodium hydroxide—0.1%	64	..	0.82	0.79	1.25	1.07	12.3	.93	4.5
Formaldehyde	Alum—1.0%	1	20	0.49	0.58	0.04	1.05	23.6	1.17	5.5
cross linking										

[a] Based on untreated, unheated controls.

reaction, the dry strength properties of the heat stabilized paper stand out most favorably compared with those of the crosslinked paper. The main advantage of a formaldehyde crosslinking treatment over a catalyzed heat treatment lies in the much higher wet strength it gives.

CONCLUSIONS

The rate of the formaldehyde crosslinking reaction is independent of the reactant concentration above 100 mg. per liter and within the limits of concentration tested. It is dependent on the nature and concentration of the catalyst whether this be acid vapor or solid salt. It is also dependent on temperature and initially proceeds linearly with the square root of time. The reaction is independent of the nature and origin of the pulp furnishing the paper. Reactant and catalyst may be applied in either vapor or liquid phases.

Embrittlement and wet strength development, being artefacts of the crosslinking reaction, are not directly dependent on the nature and concentration of the catalyst so long as the concentration is confined within certain limits. Above these limits, embrittlement is intensified and wet strength development is retarded. Embrittlement may be restricted by selecting treating conditions that prevent dimensional stabilization from exceeding approximately 40%.

A formaldehyde crosslinking treatment gives much higher wet strength properties than a catalyzed heat treatment for a comparable degree of stabilization but otherwise the heat treatment with small amounts of alkali as catalyst appears to be more favorable.

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Structural Aspects of Bonding

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The emphasis in the present discussion is on the probable physical nature of the fiber-fiber bond. The manner of bond deformation and failure should depend on the nature of the paper. In typical, well-bonded paper any one fiber is bonded to so many fibers that mechanical constraints prevent individualistic configurational changes such as twisting, and only the deformations of the fiber elements of the *system* would seem to be permitted. Accordingly, the deformation of bonds should typically be that of simple shear strain, with minimization of the kind of stress concentration associated with peeling of one thin member from another. Optical and electron micrographs have revealed a part of the role played by macro- and microfibrils in fiber-fiber bonding. The architecture of fiber-fiber bonds probably involves an interesting mechanical interaction between fibrils (most of which cannot be seen in micrographs) which project from the fibers into the surrounding water, and engage in thermal agitation. Ideas on how the mechanical biasing of these fibrils can lead to mechanical anisotropy of the bonds are reviewed. In principle, one can be sure that regular arrays of cellulose chains do not cross link in simple patterns; the geometry of the contiguous fibers governs the number and area of the regions of molecular bonding in a fiber-fiber bond and, hence, also governs the "intrinsic strength" of the bond. Two cases of bonding may exist, and in either case the Campbell effect promotes the intimate approach of molecular groups needed for molecular bonds to become established. The thickness of bonds, which relates importantly to relative fiber-fiber movement during stressing and straining of the bonds, is extremely thin. Accordingly, the relative movement of bonded fibers during prerupture shear straining is negligible in comparison with the strain response of paper resulting from the instantaneous and creep strain of the fibers themselves. Two general classes of bonds, differing in the manner in which the surface fibrils have interacted, should differ greatly in anisotropy of ultimate bond strength. In both classes of bonds, one should expect to find, in each fiber-fiber bond, a pattern of dried-in stress distribution which should affect both the prerupture behavior and ultimate strength of the bond. The work and conclusions of a number of investigators on hydrogen bonding are briefly presented. A number of factors, some of which are intrinsic to the fiber-liquid system (e.g., wet-flexibility of the fibers), and some of which are environmental, govern the creation of the fiber-fiber bonds. The paper concludes with discussions of methods for estimating bonded area, fiber-fiber bond failure, and with indications of desirable objectives for future research.

The most exciting fact about paper—known and appreciated over the eighteen and a half centuries since the invention of the product by Ts'ai Lun—is that a tough, strong sheet of material is obtained when cellulosic vegetable fibers are mechanically beaten in the presence of water and are felted together from an aqueous suspension by forming on a screen (and then dried).* This phenomenon sets paper apart from other materials. The mechanisms by which cellulosic fibers hold themselves together in paper has intrigued technical men for many years, and there is voluminous literature on the subject of fiber-fiber bonding. Discussion and classification of the various theories into such categories as the mechanical entanglement theory, the chemical theory postulating the formation of cellu-

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* In the present report, the word paper is intended to embrace paper, paperboard, insulation board, etc.

lose hydrate, and the hydrogen bond theory have been the subject of many publications. A very thorough article on the fundamentals and literature relating to fiber bonding and beater adhesives has been published by Swanson (*1*), who calls attention to a variety of molecular forces (in addition to the hydrogen bond.)

There is a need for more discussion of the *structural* aspects of fiber-fiber bonding and, to meet this need at least partially, the present paper has been prepared. In the interest of completeness, this discussion includes some comments on recent work relating to the molecular aspects of bonding.

The relationship of fiber bonds to the mechanical properties of paper (which includes consideration, for example, of the way in which the bonds deform and ultimately fail) should depend, theoretically, on the nature of the paper. The behavior of bonds during straining of paper should depend on whether there are very few bonds between a typical fiber and other fibers, or many bonds. Some writers feel that the fibers are free to twist and change shape when paper is strained, or when the sheet gives up or takes on moisture. The weight of evidence favors the view that a typical paper sheet is a strong, well-consolidated system of fibers, with *many* points of bonding between a typical fiber and other fibers. A portion of the evidence is found in ordinary microscopic examination of paper. Information of a somewhat more quantitative nature may be found in measurements of effective pore size; for example, the work of Carson (*2*) and of Bublitz, *et al.* (*3*) shows that the effective pore size lies typically in the range, 10^{-5} to 10^{-4} cm. This implies hundreds of points of contact, if not of actual bonds, between one fiber and other fibers. Considerations of the geometry of sheet structure lend further support to this numerical estimate. The evidence, then, is that the typical fiber is not free to twist, change shape, or to slip in any appreciable way in reasonably strong paper; only the deformations of the fiber elements of the *system* would seem to be permitted. To complete the picture of the system of fibers, the fibers in a conventional machine-made web lie roughly in planes parallel to the two surfaces; the individual fibers are never straight; fiber orientation in planes parallel to the surfaces of the web is such that the appearance of distribution in angle of fiber elements is quite random—as is well known, the so-called "fiber alignment" occurring in machine-made papers is a relative term which means only that a statistical distribution curve displays maxima in the machine and antimachine directions and minima in the two cross-machine directions (*4*). Mental pictures or theoretical models of paper which present aligned or parallel filaments may lead to highly erroneous concepts and theories concerning the nature and behavior of paper. When actual paper is subjected to strain in any direction in the xy plane,* one can find numerous well-bonded fiber elements within a fairly small angular range of that direction. Further evidence for this picture of a strong, rigid network of fibers and of its extensive and intensive system of fiber-fiber bonds is found in recent work on the incidence of fiber failure during both tearing and tensile rupture of paper (*5*).

* In dealing with sheet properties, it is convenient to designate the machine direction as the x axis, the cross-machine direction as the y axis, and the direction normal to the sheet as the z axis.

In view of the enormous complexity of paper regarded as a structural system, theories cannot be exact, but may only be semiquantitative; ultimately, it may be possible to develop theories which may be designated with the term *statistical viscoelasticity*, by analogy to statistical mechanics (*6*).

The importance of the concept of paper structure to the first rudimentary steps in the development of theory can be easily illustrated with the following examples. To make this clear, let it be assumed, with some writers, that the typical fiber is bonded only at several points to neighboring fibers. When such a sheet is strained, the fiber-fiber bonds would be subjected not only to simple shear, but also to shear associated with torsional strain (about the z axis)—in a manner crudely analogous to that occurring in a joint of a "lazy tongs." Within each bond, stress concentration should occur in the manner of that observed when one thin member, in adhesive contact with another, is peeled away. Further, the fiber itself would undergo appreciable change in shape during the straining of the sheet, such as straightening of a segment between points of bond, twisting, etc.

Let it now be assumed that the number of bonds of one fiber to others is quite large, as pictured earlier for typical paper. The stressing of fiber-fiber bonds, in this case, is visualized as simple shear, with minimal twisting and peeling effects; in this model, there would be little or no gross configurational change in individual fibers. This discussion will suffice to show that the nature and degree of straining of fiber-fiber bonds depend markedly on the model adopted for the paper web.

ARCHITECTURE OF FIBER-FIBER BONDS

In the following discussion, we assume that the stock has been subjected to sufficient mechanical treatment to remove most of the primary wall from the fibers, so that the words "fiber-fiber" bonds embrace a substantial amount of fibril-fiber and fibril-fibril bonding, as well as fiber-fiber union. Through studies with the light microscope, the phenomenon of fibrillation (the mechanical peeling, tearing, teasing of fine filaments from the fibers) has been known for many years. The development of the electron microscope and of its application to the study of fibers revealed the interesting fact that many of the fibrils have thickness ranging down to the limit of resolution of the first instruments [for illustrative electron micrographs and references to the earlier literature see, for example, Sears and Kregel (*7*)]. Modern electron microscopes, with resolution in the range 10 to 20 A, employed with optimum shadowing and replica techniques, appear to confirm the findings of Meyer (*8*) and of Rånby (*9*) to the effect that, beyond the long chain cellulosic molecules, a basic element of all fibrils is a microfibril having an oval cross section and a mean diameter in the vicinity of 80 A. The importance of fibrils of all sizes, and of fragments of primary and outer secondary wall of the fiber, comprised of fibrils, is well illustrated in the excellent electron micrographs obtained in various laboratories throughout the world. Mention may be made of the work of Emerton and his colleagues, which has been presented in Emerton's "Fundamentals of the Beating Process" (*10*). Jayme and Hunger have published a

series of papers in which they have introduced very interesting electron micrographs, the last of which cites references to eight earlier publications (*11*). In an excellent series of papers [the most recent of which (*12*) presents very interesting electron micrographs and citations to earlier work] Asunmaa and Steenberg discuss and illustrate the nature of the fiber-fiber bond in paper.

The light and electron microscope replica pictures of Emerton and of Jayme and Hunger show very clearly the complexity of the fine structure of paper and of the roles played, in bonding, by P and S_1 layers of the fiber wall. Particularly noteworthy are the stereo electron micrographs obtained by Jayme and Hunger. Of considerable interest to us in the present discussion are Asunmaa's electron micrographs. Except for several hundred photomicrographs taken with the phase contrast microscope, her work (involving about 2000 electron micrographs) was done by electron transmission of ultrathin sections taken from very light paper sheets prepared both by forming on a wire and by sedimentation from water on Teflon foil. Microscopic regions of bonding between two or more fibers were "electron stained by metallic osmium" and embedded in methacrylate; the sections were prepared by means of the Sjöstrand ultramicrotome, without removal of the polymethacrylate. The sheets were prepared from bleached, strong sulphite pulp (Norway spruce) and bleached kraft pulp (Swedish pine) beaten at four widely spaced intervals in the PFI laboratory beater. Several of the observations and conclusions presented by Asunmaa and Steenberg (*12*) may be quoted as being of interest to this discussion.

1. "Apart from the observations that a great many fibers appear more or less undamaged even after a prolonged beating and even if studied in electron micrographs, a pronounced increase of the fines with increased beating is noticeable."

2. "From classical optical investigations, it has often been concluded that the first bearing action consists of a splitting and peeling off of the primary wall. The electron microscope studies indicate that the splitting usually occurs in such a way that the outer secondary wall S_1 is frayed and partially destroyed, more or less completely removed and sometimes fixed to the S_2 only at a few points. Even in pulps of a low beating degree, the S_1-layer was often completely or almost completely removed." (The authors go on to say that the morphological differentiation between S_1 and S_2 is simplified because of the strong difference, observed by them, of the impregnation of these layers with osmium, more going into S_1.)

3. "According to this kind of analysis, it is concluded that a very intimate, optical contact can exist between all distinguishable structural layers and components of the fiber wall. Thus, contact areas of considerable magnitude have been observed between S_1-layers of different adjacent fibers, between the S_1-layer of one fiber and the S_2-layer of another and between the S_2-layers of two fibers. Similarly, new contact areas have been observed in the collapsed lumina of the single fibers. . . ."

4. "The contact area may assume sizes ranging from almost a point contact up to 100 sq. μ. Although no statistical study has been carried out, the pictures give an impression that the sum of the areas of many small scattered point contacts, frequently embracing fines, is considerably smaller than that of the fewer but considerably large contact areas. The larger areas occur between fairly 'intact' fibers. The 'intact' fibers refer to fiber walls not showing apparent dislocations and destructions, except for the removal of the S_1-layer or some papermakers 'fibrillation.'" (Apparently the authors have referred to the fibrillation of the S_2-layer at the ends of a fiber as "papermakers fibrillation.")

5. Having pointed out that the resolution is about 20 A., the authors state, "Distances observed between structural components are frequently short enough to make plausible that chemical bonds exist between fibers."

These observations have a strong bearing on one's concept of the "architecture" of fiber-fiber bonds. There are three classes of fiber-fiber bonds (S_1-S_1, S_1-S_2, S_2-S_2) and, thus, one would logically anticipate that there will be at least three levels of what has commonly been referred to as "intrinsic bonding strength." The demonstrated bonding, *within* the fiber, of the lumen surface has an obvious bearing on significance of the optical method for relative bonded area, and relates to z-tensile strength, if not to mechanical properties in the x and y directions. Clearly demonstrated is the usual supposition that bonds of substantial area (e.g., 100 sq. μ) exist between contiguous fibers. As stated by the authors, the fibers are intimately bonded together, and it is plausible that the bonds are chemical (as contrasted, for example, with tenuous bonds in which the fibers might be separated by more than 20 A., with many microfibrils bridging the gap).

We turn now to important structural considerations of the fiber-fiber bond. The outer surface (of P, S_1, or S_2) presented by a fiber of a beaten pulp is a fairly regular pattern of macrofibrils which, in turn, are composed of microfibrils [see, for example, the papers and discussions presented at the Cambridge Symposium (*13*)]. There would seem to be at least two possibilities: case I. The surface fibrillar system is essentially intact; case II. A substantial percentage of the macro- and microfibrils have been *partially* torn away from the surface system by the refining and other mechanical actions (pumping, screening, etc.), so that the surface of the fiber presents a microscopically fuzzy appearance: the macro- and microfibrils project from the fiber into the surrounding water; these exceedingly fine filaments are in ceaseless, random, jerky motion ("Brownian motion" or thermal agitation). Electron micrographs could be expected to give only a hint of this microscopically fuzzy condition of the fiber (*occurring when the never-dried fiber is submerged in water*) even where examination has been made of fibers dried from liquids other than water. Surface tension of the liquid from which the fiber is dried (in preparation for electron microscope examination) causes the fibrils to be brought back upon the surface of the parent fiber. However, one can feel reasonably sure that the surfaces of beaten fibers, suspended in water, present a fuzz or "pile" of extremely fine cellulosic filaments. (The light microscope can be used for observation of fibers submerged in water, but no adaptation of the light microscope has sufficiently good resolution to reveal the fibrils in the range of size indicated.)

The structural nature of the fiber-fiber bond would depend very importantly on whether case I or case II represents a given actual state of affairs. In case I, it would seem that molecular bonds would occur only in the more or less regular array of points corresponding to intersections of two sets of roughly parallel ridges, with the angle between the two systems lying somewhere between 0 and 90°. Each of the many points of intersection between the two sets of surface fibrils is a center of a very small region of molecular bonding, and it seems likely that the regions lying between these areas of molecular bonding would be too remote for hydrogen

bonding (or for any other known molecular force) to be effective. Thus, the *apparent* area of bonding between two ribbonlike fibers is probably much greater than the total actual area of molecular bonding. The picture just presented for case I is undoubtedly overly idealized in view of the intrinsic irregularity of the surface of fibers [see, for example, the many replicas of fiber surfaces presented by Emerton (*10*)]. The possible geometries of hydrogen bonding such as those presented in Figs. 6, 114 and 115 of Emerton's book (*10*) could apply only over exceedingly short distances.

The intimacy and degree of completeness of all the types of bonds which may be visualized for both case I and case II are promoted by the "Campbell effect" (*14*), which operates during the drying of the web.

The structure of the fiber-fiber bond corresponding to case II is radically different from that just pictured for case I. When two fibers approach each other (in water), the first mechanical interaction would obviously be between the innumerable macro- and microfibrils which project from the surfaces. The two systems of fibrils, each pictured as in violent, random agitation, are visualized as approaching each other with entangling movements. Bonds are made and broken by reason of the thermal agitation. Superposed on the random motions one would expect local mass movement, as in a waving field of grain on a windy day, the "wind" in this case being relative motion of the water arising from flow and relative movement of the fibers. If the web dries under tension in a given direction, and the elements of fibers and fibrils are drawn together by the Campbell effect, only a *very slight* relative motion between contacting fibers in the direction of tension will suffice to produce at least a partial alignment of the projecting fibrils which have established contact with fibrils from the other fiber. This, indeed, is the explanation presented by Steenberg, as quoted by Edge (*15*) in a partial explanation of Edge's findings regarding the enhancement of tensile strength in the direction of tension during drying. [Although the hypothesized anisotropy of the bonds is potentially an important factor, many people believe that the effect of drying under tension on the configuration of the *fibers*—in such manner as to cause each fiber to share more equally in the tensile loading in the given direction—is the more important factor; the fiber configurational change resulting from drying under tension should require a greater stress in the sheet for any given strain in the direction of drying tension (*6*).]

Whether (in case II) the intermeshing fibrils become partially aligned or arrange themselves randomly (depending upon the mechanical conditions of drying), without doubt the intermeshing fibrils become bonded not only to each other, but to either or both of the parent fibers. It is obvious that the mechanical properties of bonds of case II should be quite different from those of case I.

It would seem that an important structural aspect of the fiber-fiber bond is the thickness of the bonded zone. One is accustomed to think of *adhesive* layers as thin and, indeed, such layers are thin when the thickness is expressed in ordinary terms. However, adhesive layers are often thousands of angstroms thick—hundreds of times the distances over which molecular forces can act. *Cohesive* bonding between uncontaminated surfaces of the same material involves separations (*at the points of bonding*) of the order of only several angstroms. In the case of the fiber-fiber bond, it is believed that the thickness of the bonded structure is extremely thin (*6, 12*). A case I bond, pictured in the foregoing, would obviously be only a few angstroms thick in the small regions where hydrogen bonds and other molecular forces exist. In case II bonds, the thickness of the bonded structure would obviously vary from a few angstroms (where undisturbed fibrillar surfaces are in contact) to thicknesses corresponding to the sandwiching of one, two, or several fibrils—perhaps of the order of 50 to several hundred angstrom units. In any case, the thickness of the bonded structure is exceedingly small in comparison with the linear dimensions in the xy plane of the general area of a fiber-fiber bond (typically of the order of 200,000 A.). As will be seen in the next section, the thickness of the fiber-fiber bond is important to one's ideas concerning the stress-strain relationships of bonds.

STRESSES AND STRAINS IN BONDS

The hypothesis has been advanced earlier that, in a typical well-bonded sheet of paper, the individual fiber-fiber bonds are subjected to simple shear stress when tensile stress is applied to the web in the xy plane. Accordingly, the prerupture response of the bond is pictured as a simple shear strain whether the bond is of case I or case II; the thickness of the bond is so small that the displacement of one fiber relative to the other (to which it is bonded) is small enough to be regarded as *completely negligible in comparison with the strain in the web associated with instantaneous and creep strain of the fibers themselves.* A little arithmetic will illustrate the importance of this consideration: a shear strain of 0.1 radian would be quite large; yet, if the effective bond thickness (case I) were 2.8 A., the displacement of one fiber relative to the other would be only 0.3 A. If the bond is of case II and has a thickness of the order of 100 A., the relative displacement would be 10 A.—a completely negligible movement when compared with the linear dimensions in the xy plane of a fiber-fiber bond.

If tensile stress is applied in a direction parallel to the z-axis (as in the measurement of "transverse tensile strength"), the stress and strain in the bonds are, of course, of the normal kind. Here, also, the response of the sheet attributable to the strain of the bonds is negligible.

When the rupture of a bond is imminent (whether the stressing load is applied in the xy plane or in the z direction) it seems likely that stress concentration will occur at the periphery of the fiber-fiber bond. Although it is theoretically possible for molecular bonding sites to slip with the breaking and reforming of bonds (as in Eyring's theory of viscoelasticity of high polymers), the opinion is here expressed that, when two macroscopic bodies such as fibers are bonded together, failure, once started, will proceed rapidly to complete an irreversible destruction of the bond.

With respect to the ultimate strength of the fiber-fiber bond, one should expect an interesting difference between the behaviors of case I and case II bonds. While there is no reason to believe that case I bonds would be perfectly isotropic in the xy plane, there is no

doubt that case II bonds, mechanically biased by drying under tension, as described in the foregoing section, could be strongly anisotropic. The expectation, of course, is that the bond would contribute most significantly to that ultimate stress in the web which causes the bond to be strained in a manner similar to that existing when the web was dried under tension. An interesting question arises: having established the direction and magnitude of a maximum shear stress which the case II bond will withstand, can the direction of the stress be reversed without rupturing the bond? It would seem that the strength of the bond for the reverse direction of shear could be of a decidedly lower magnitude. This follows from the consideration that the intertwining system of fibrils are bonded to each other and to the parent fibers and have been so disposed by the straining while the web dried under tension as to cause all elements to share the load and minimize stress concentration effects; on reversing the shear stress, stress concentration effects would become large and, accordingly, the strength of the bond would be small. Unfortunately, there appears to be no experimental means for dealing with this aspect of anisotropy of fiber-fiber bonds. (Reference has already been made, in the foregoing section, to the expected anisotropy of case II fiber-fiber bonds in the sense that such bonds should be much weaker for a force applied in the y direction than for one in the x direction which will stress the bond in a direction similar to that which obtained when the sheet was dried under tension.)

Much has been written about "dried-in" stresses and strains in paper. Careful analysis reveals that many kinds of configurational modifications can result in the fibers and in fiber-fiber bonds as a result of all the actions of sheet forming, pressing, and drying. We shall consider here only one further configurational effect in a fiber-fiber bond. This is the local configurational change and stress distribution associated with the fact that when two fibers, A and B, bond together, both fibers, in the final stages of drying, tend to shrink appreciably in directions perpendicular to their respective axes, while exhibiting very little change in their axial dimension. The effect would seem to be at a maximum when A and B intersect at, or near, 90°; in the zone of the bond, each fiber will be under axial compressive stress and lateral tensile stress. Accordingly, in a well-bonded sheet of the kind earlier pictured, one should expect to find a pattern of dried-in stress and strain: on following any path which lies in the plane of the bond and passes through the center of the bond, the shear stress and strain should proceed from a maximum at the boundary of the bond through zero at the center to a maximum in the opposite sense at the other boundary. In other words, *maximum dried-in shear stresses should exist around the periphery of the fiber-fiber bond.* In consideration of the fact that stressing of the bond resulting from externally applied forces causes a stress concentration at the periphery of the bond, this dried-in stress has an important bearing on the resistance of the bond to rupture when the whole web is subjected to loading. For certain boundaries of a single fiber-fiber bond, the dried-in stress and the stress resulting from external loading will be additive, while at the other boundaries the dried-in stress will aid the bond in resisting the disruptive effect of the applied load. Failure will, of course, initiate in the former regions, where the stresses are additive; it is expected that the effect on bond strength of dried-in stress of the kind described is quite appreciable. Realization of the importance of the dried-in stress in a fiber-fiber bond is enhanced when one considers that (1) the dried-in stress is maximum at the periphery of the bond, and (2) stress concentration resulting from an externally applied load is also to be found at the bond periphery (*6*). It may be mentioned, in passing, that dried-in stresses of the kind discussed above constitute one of many factors underlying hygroexpansivity or dimensional stability of paper.

MOLECULAR NATURE OF FIBER-FIBER BONDS

The nature of molecular forces constituting the bonds between cellulosic fibers has been adequately discussed elsewhere. Reference has already been made to the comprehensive review and discussion by Swanson (*1*). Rånby has recently given a useful review of theoretical and experimental work on the hydrogen bond (*16*). Reference has earlier been made to some possible configurations for hydrogen bonding between cellulosic molecules with and without one or more layers of intervening water molecules (*10*).

The best experimental evidence that hydrogen bonds are involved in the cohesion between the fibers of a paper web has been presented by Corte and Schaschek (*17*) and Corte, Schaschek, and Broens (*18*). Pointing out that it is known from spectroscopic work that, in papermaking fibers, almost all the hydroxyl groups are involved in hydrogen bridges and that (presumably) only a small fraction of all the hydroxyl groups is available to form additional bonds between the fibers when the web is formed, these authors raised the question, "... how many hydroxyl groups are used for these interfiber bonds, furthermore, what is the strength of a single bond?" In an attempt to answer this question, they exchanged H_2O in paper with D_2O (sheets exposed to a mixture of H_2O and D_2O vapor for a sufficiently long period of time for equilibrium to become established). Their plots of the ratio, [D]/[H] against per cent deuteration exhibited sharp, sudden breaks above which (on the per cent deuteration scale) [D]/[H] remains nearly constant at a value close to 0.05. The point of break, in each case, relating to the equilibrium substitution of D_2O for H_2O corresponds to the saturation of the available hydroxyl groups. Significantly, the level of deuteration for a paper sheet formed from beaten fibers is less than that corresponding to a mass of beaten but free (unbonded) fibers. The authors state, "As a general result, it has been found that the amount of hydroxyl groups forming the interfiber hydrogen bonds lies in the order of 0.5 to 2% of all hydroxyl groups present."

Corte and his co-workers then attempted to relate the energy required mechanically to break paper and the hydrogen bond energy. Recognizing that most of the energy going into a test strip of paper is accounted for by strain energy and energy that is dissipated within the strip by various mechanisms, and that only a minute amount of the observed energy is utilized in breaking molecular bonds, Corte, *et al.*, attempted to estimate the small portion of the energy which goes into the breaking of fiber-fiber bonds. This effort required the

determination of energy to rupture of test strips of various span lengths and an extrapolation of an experimental curve to zero span length. These investigators were surprised to find that their experimentally determined energy to break fiber-fiber bonds was of the order of 2 to 10 times the theoretical energy (and they pointed out that it is unusual for a determination of this sort to result in an energy which is *larger* than the theoretical value). There is no doubt that their work, in this area, suffers, at least to some extent, from an experimental error which was apparently unrecognized by them. This is the disturbing effect of "partial jaw pull-out," which occurs in the conventional recording of load-elongation or "stress-strain" curves for paper (*19*, *20*). The nature of the error arising from "partial jaw pull-out" is such that its relative magnitude increases with decreasing span length, so that, for example, an energy value obtained by extrapolation to zero or to a very small span length may be in error by an appreciable factor. While it is intriguing to obtain an experimental value which is of the same order of magnitude as one calculated from theory, the accuracy of the result is certainly not good enough to permit the conclusion that bonding on the molecular scale is necessarily hydrogen bonding. However, the work of Corte, *et al.*, on deuterium exchange appears to demonstrate, without doubt, that hydrogen bonding is involved in the fiber-fiber bond.

Knowledge of the importance of the role of water in the forming and bonding of paper goes back many years; special reference should be made, of course, to the classic work of Kress and Bialkowsky (*21*). In a more recent work, Broughton and Wang (*22*) have demonstrated that the wet strength of paper is related to the hydrogen bonding power of the liquid in which the paper is immersed.

It is clear that a great deal more work remains to be done on the relative importance of the hydrogen bond and of other kinds of molecular bonds to the fiber-fiber bond.

Before passing to the discussion of factors governing the formation of fiber-fiber bonds, it would be well to refer to the interesting papers on the effect on paper strength characteristics of acylating cellulose; among these may be cited the work of Brown and H. Ainsworth Harrison (*23*), Bletzinger (*24*), Aiken (*25*), and J. J. Harrison (*26*). These investigations clearly reveal the importance of the hydroxyl groups in the bonding of fibers. However, the combination of *all* molecular forces might well be synergistic; the hydrogen bonds may permit the existence of other molecular forces which contribute significantly to the total energy and strength of the fiber-fiber bond.

FACTORS GOVERNING THE CREATION OF FIBER-FIBER BONDS

Molecular forces of all the recognized types become essentially inoperative for distances greater than a few angstrom units. When a paper web is formed on a wire screen the total area of regions in which fibers and fibrils *happen* to approach each other with separations less than, say, 5 A. must be an extremely small fraction of the total external surface area. Wet pressing undoubtedly increases very greatly the total area of these regions. However, when the compressive stress is released, the elastic nature of the wet fibers (although of a low order) causes the network of fibers to expand ("spring back") and many of the close approaches formed by the compressive action enlarge to separations far beyond the effective ranges of the molecular force fields. As is well known, any fiber-fiber bonds formed in the presence of water are exceedingly weak. Nevertheless, wet pressing greatly augments the desirable actions of the Campbell effect (*14*); this effect, and the paper to which reference has already been made, are both so important that all persons interested in papermaking are especially urged to read Campbell's discussions. Campbell discusses how, during the drying of a sheet of paper, substantial tensile stresses develop in the minute regions of water existing between fibers, between fibers and fibrils, etc., and how these large tensile stresses draw the elements of the fibrous structure together closely enough for molecular force fields to "take over"—thus establishing strong fiber-fiber bonds in the final, dry state of the web. The Campbell effect creates the proper environment—the extremely close approach between fibers and fibrous elements—for molecular bonding to come into existence.

An essential aspect of Campbell's theory is the high flexibility and plasticity of water-swollen fibers. As is well known, only water and other highly polar liquids which cause the fiber to swell on imbibition of the liquid will promote a wet flexibility which is orders of magnitude higher than the dry flexibility.

Because of the theoretical importance of wet flexibility of papermaking fibers to the formation of strong paper, considerable effort has been expended in a number of laboratories to gain more information and a better understanding of water-cellulose relationships. Techniques have been developed, such as that employed by Jayme and co-workers (*27–29*), to obtain at least approximate measures of the water imbibed by papermaking fibers and how such water content is affected by beating and other actions.

There is a great need for a more accurate, more direct measurement of the wet flexibility of fibers. A number of factors are believed to have appreciable influence on the wet flexibility of papermaking fibers; some of these are chemical, or constitutional, such as lignin content and the nature and distribution of hemicelluloses. The capacity of the hemicelluloses to promote sheet strength has been variously ascribed to adhesive effect and to influence on the wet flexibility of fibers. It would seem that definite conclusions cannot be made about the influences of chemical factors until accurate methods for measuring wet fiber flexibility are developed.

From the viewpoint of classical theory of structures, the flexibility or stiffness of a system like that of a papermaking fiber composed of long filamentous elements depends markedly on the resistance of the system to sliding of the elements in the axial direction; if the elements are strongly cross-linked, the system will be rigid, and this is generally considered to be the situation for dry fibers. If, however, a swelling liquid like water can, as a result of energy changes, insinuate itself into the noncrystalline regions of the macro- and microfibrils, the stiffness of the system will become dramatically reduced. The well-known beneficial effects

of an optimum content of hemicelluloses is believed to be due, at least in part, to the contribution of these compounds to the swelling and reduction of stiffness of papermaking fibers (*30–32*). No attempt will be made here to review all of the work on the various supposed actions of the hemicelluloses; excellent reviews and discussions have been presented by Wise (*32*), Cottrall (*33*), Swanson (*1*), and Emerton (*10*).

Finally, of course, the fiber architecture itself, and how this is disturbed by beating, should have a strong influence on the formation of fiber-fiber bonds. As is well known, the fibers within a given pulp exhibit a wide range in fiber wall thickness; the "springwood" fibers are much more flexible than the thick-walled "summerwood" fibers, and where investigators have separated the two classes (by splitting or shaving wood before pulping), it has been found that denser, more completely bonded paper can be made from the springwood fibers. Apparently, for the given actions of wet pressing and the Campbell effect, the appreciably more flexible springwood fibers display larger local deformations and become more generally bonded to one another. Reference has already been made to another way in which different classes of fibers may respond to the forces which tend to create bonds; for the same wet flexibility and plasticity, the number of bonding sites of contiguous fibers is expected to depend upon the geometry of the fibrillar surfaces, with particular regard to contour of the surface, partial disruption of fibrils from the surface, location of bonding sites with respect to orientation of surface fibrils, etc.

The theoretical expectation is that temperature should influence the formation of fiber-fiber bonds primarily through the dependence on temperature of the Campbell effect, the wet flexibility of the fibers, and the thermal agitation of molecular groups existing during the bond formation. A lowering of temperatures should enhance the Campbell effect, the degree of fiber swelling, and probably also, therefore, the wet fiber flexibility, and improve the completeness of bonding through reduction in thermal agitation (increased viscosity of the water is probably not an important factor, in view of rate considerations). Common paper mill experience indicates that a lowering of temperature tends to improve the effectiveness of beating (or of refining) and to augment such strength characteristics as bursting strength and tensile strength. This statement is only of passing interest, and is not offered as "proof" of the foregoing theoretical remarks!

There are many *external* factors (beyond that of wet pressing), such as those of the paper machine, which would have an important bearing, theoretically through the factors discussed in the foregoing, on the formation of fiber-fiber bonds. While a speculative discussion of these factors would be of interest and possibly of value, such a discussion is not considered pertinent in the present report.

ESTIMATION OF BONDED AREA

For many years, in an attempt to separate variables, men working on the mechanical properties of paper have attempted to deal with the *extensiveness* of the *intrinsic strength* of fiber-fiber bonding. Proceeding on the fact that the optical scattering power of paper is related generally to the degree of beating and tensile strength, Parsons (*34*) originated the optical method for estimating the relative bonded area in a sheet of paper. During the intervening years, the Institute Physics Group (*35*) has improved the optical and other laboratory techniques of the procedure, and the method has become rather widely employed. The basic assumptions of the method [*viz.*, (1) the specific scattering coefficient is proportional to the unbonded area of fibers and fibrils, and (2) a region in "optical contact" is, in fact, a bonded region] are of such a nature that the theory could not be exact and the method should be used only for the purposes of estimation. Age of the optical method and fairly frequent reference to it in the literature have both, unfortunately, lent "authority" to the technique. The method, in the laboratories in which it has been developed, has always been regarded as crude in its theoretical basis and refined in its precision of measurement. Some of the difficulties were brought out by the work of Haselton (*36*) and, following Haselton's lead, Ingmanson and Thode (*37*) conducted laboratory work on a modification of the method which obviates the preparation of an "unbonded" sheet through successive replacement of water by acetone and butanol. New information about the significance of the method is gradually being accumulated, and it is possible that further developments will some day give the method accuracy as well as precision.

For research purposes, deuterium exchange, as exemplified by the work of Corte, *et al.* (*17, 18*) might be effective for measuring interfiber bonding; the method, however, should be sensitive to *intrafiber* changes promoted by beating or other treatment of pulp fibers, and this must be properly taken into consideration. In a similar category is the gas adsorption technique, as exemplified by the work of Haselton (*36*), which is especially sensitive when the gas employed is krypton (*38*). Included in "intrafiber changes" are bonding in the lumen and in the wall pore structure of the fiber. Mention should be made of the consideration that the way in which a total observed interfiber bond area is arrived at is important (see the section on "Architecture of Fiber-Fiber Bonds"): (1.) At one extreme, it may be the area of bonding together of ribbonlike fibers (case I), and (2.) at the other extreme it may be the area of bonding together of innumerable fibrils resulting from intensive beating or refining of the pulp (case II). Ultimately, the further factors relating to the structure of bonds, discussed earlier in this report, must be taken into consideration in a proper study of intrinsic bonding strength.

ESTIMATION OF FIBER-FIBER BOND FAILURE

In a very interesting and valuable series of papers, Nordman and his colleagues have described the application of special optical techniques to utilize the optical method for evaluating the breaking of bonds in paper either during, or following, the application of stress. Reference may appropriately be made to a recent paper by Nordman (*39*), which includes a listing of earlier publications. Nordman's technique is based on the finding that, as a sheet of paper is strained toward the breaking point, the optical specific scattering coefficient increases and, if a sheet is strained to a point short of rupture, and the stressing is removed, the scattering coefficient does not reversibly return to the initial value.

Nordman and his associates attribute the change in scattering coefficient to the breaking of bonds and find that, for a given pulp, irrespective of the degree of beating, the change in specific scattering coefficient is linearly related to the energy loss in a straining/destraining cycle. This, incidentally, is related by Nordman to the energy required to rupture hydrogen bonds. When, however, the Nordman results are interpreted to yield measures of *fiber-fiber* bond failure, certain difficulties arise (*40*). One of these is that *intrafiber* bond breaking is a likely possibility, i.e., one would expect bonding in the lumen and in the fiber wall to be disrupted by stressing of the fiber. Another difficulty is that the straining of paper will probably cause those regions of nonbonded optical contact irreversibly to become smaller, thus causing a rise in specific scattering coefficient. This last difficulty has been brought out by Valley (*41*) and by Andersson (*42*).

FUTURE RESEARCH

Throughout this discussion, the need for further research is either stated or implied. Many of the problems touched upon are not amenable to direct observation or experimentation; it is hoped that, as truly fundamental work is done, new and powerful scientific techniques will permit studies, for example, of the nature of fibrillar surfaces of never-dried fibers suspended in water, of the structure and mechanical properties of fiber-fiber bonds, of the shear and tensile stresses induced in fibers when the sheet is subjected to tensile loading, of the way in which fiber-fiber bonds fail in paper, of the effect on strength of dried-in stresses in the fiber-fiber bond, of the contribution to the strain response of paper resulting from deformation of fiber-fiber bonds, of the internal phenomena associated with flexure of wet fibers, etc., and will permit the development of new techniques, such as one for the accurate measurement of wet fiber flexibility. With improvement, some of our present techniques will become more powerful and exact, but it seems desirable to adopt the attitude that most of these techniques are basically crude and should be used for the purposes of estimation only until more scientifically accurate tools of research and methods of study are created.

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Fiber Geometry as Related to Paper Bonding

RENATA MARTON

This study deals with morphological changes in fiber structure and the geometry of high-yield pulps brought about by delignification, refining, and wet pressing and their effects on paper properties. Pulp has been produced from white birch (*Betula papyrifera*, Marsh.) by a cold soda technique, in 77.3% yield, then delignified by sodium chlorite from the original 19% to levels of 12 and 2.3%. Handsheets were prepared from pulps at these three lignin contents under varying degrees of ball milling and wet pressing. The extent of removal of the primary wall and outer layers of the secondary wall was measured in order to assess the potential active fiber surface. The "swellability" of the fibers was determined for the different refining treatments which were imparted. Apparent density and tensile strength have been related to the extent of removal of the primary wall and the outer layer of the secondary wall and to the "swellability" of the fibers at different degrees of beating and wet pressing.

From these relations it was observed that the strength development was not only a function of P and S_1 removal, but depended on other changes in the cell structure which are better reflected in the "swellability" of the fibers. In examining the cross sections of the corresponding paper specimens, the effects of wet pressing, refining, and lignin removal were seen to change the packing of the fibers in the handsheets, and to deform the fibers.

THE STRENGTH of paper depends to a great extent on the number of bonds formed between the surfaces of the adjacent fibers. The number of bonds formed is determined chiefly by chemical composition and physical characteristics of the outer layers of the cell wall. These factors can be altered by delignification, beating, wet pressing, and other processes. Several investigations have been made to determine the effects of beating and wet pressing of chemical pulps, low in lignin content, on fiber structure and interfiber bonding. In contrast, this work deals with high-yield pulps and their partially and wholly delignified products and the changes in structure and geometry of these fibers brought about by refining and wet pressing. The opportunity to initiate this study arose when high-yield, white birch pulps were prepared for a rheological study by Karna (*1*) in these laboratories.

The primary objectives of this investigation may be outlined as follows:

1. To measure the extent of removal of the primary wall (P) and outer layers (S_1) of the secondary wall in order to assess the potential "active fiber surface" for the different treatments applied to the pulps.
2. To study the degree of swelling produced by beating, wet pressing, and delignification.
3. To study the cross sections of the corresponding paper specimens in an attempt to determine the portion of the potential "active surface" utilized in bonding.

During the chemical digestion of wood the middle lamella is removed long before any visible physical change can be observed in the wall substance of the fiber. Immediately after sulphite or sulphate cooking, the fibers, according to Giertz (*2*) are still covered with the P layer, but it is only loosely bound to the main body and is easily removed during the blowing of the digester and in subsequent refining of the pulp. When the fiberization of wood is accomplished by a combination of chemical and mechanical means (semichemical pulping), there is partial dissolution (to various degrees) of the chemical components of wood, but generally not to the same degree as in chemical pulping. Therefore, depending on the conditions used for fiber separation, the failures may occur between the fibers, along the middle lamella, and across the fiber, as well; consequently, a wide variation in surface properties of the fibers results. These fibers, as expected, will respond differently to the subsequent refining treatments. During beating of the chemical pulps, fibers are reduced in length, and their P and S_1 layers are damaged. The partial removal of these membranes makes the inner layers of the cells accessible for swelling (*3–7*), and as a result, improved flexibility of the fibers is achieved and this effect contributes to better bonding.

Wet pressing of the slightly beaten chemical pulps is generally regarded as an effect similar to that obtained by increasing the beating time (*8, 9*). Both actions lead to the closer contact of fibers in paper, i.e., increased paper density. This is in agreement with Doughty's (*10*) findings in his investigation on wet pressing. On the basis of his work, Doughty proposed that the apparent density is one of the best indices of the interfiber bonding.

Giertz (*11*) found a simple correlation between the removal of the primary wall and the development of paper strength during beating. Giertz also points out that, because of other destructive effects which occur at the same time during beating, the development of paper strength cannot be related with certainty only to the effect of P and S_1 removal.

Gallay (*12*) states that the removal of the P alone is not sufficient for promoting bonding, but that "adhesive materials" must be generated.

It must be kept in mind, however, that the above discussion is concerned mainly with chemical pulps. It might be expected that in the high-yield pulps containing large amounts of hemicelluloses—"a swellable built-in adhesive"—better interfiber bonding should result. The high-yield pulps, though they contain hemicelluloses in large amount, are not amenable to unrestrained swelling. In this connection, Jayme and Mohrberg (*13*) demonstrated that lignin itself not only resists swelling, but it also acts as an "inhibitor" for the swelling of hemicelluloses. This is easy to accept if lignin is considered to be a three-dimensional network. In their studies on cold soda pulping of eucalyptus, Dadswell *et al.* (*14*) stated that the response of these pulps

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Table I. Lignin and Pentosan Content of White Birch Pulps

	I	*II*	*III*
Lignin %	19.0	12.0	2.3
Pentosan %	12.8	11.4	8.0

to beating is much lower than that obtained with chemical pulps from the same wood. The main action of the beating, according to these authors, is the disintegration of residual fiber bundles into individual fibers. At the same time the stiff fibers are made more pliable.

In studies on interfiber bonding much emphasis has been placed on the free surfaces of the fibers and also on the bonded area in the paper. Little attention has been given to the actual nature of the fiber surface. Giertz, on the other hand, endeavored to relate interfiber bonding with the properties of the surface. It was felt that his method is valuable, and that with further development, it could yield more useful information on the nature of the exposed cell wall material and its relation to interfiber bonding. Specifically, measurements for swelling as suggested by the works of Sergeeva and Miljutina (*15, 16*) could be applied to yield quantitative indices of the changes incurred by the fibers during physical and chemical treatments.

EXPERIMENTAL PROCEDURES

Pulp Preparation

Cold soda pulps from white birch (*Betula papyrifera* Marsh.) were prepared in 77.3% yield by chip breakdown during the alkaline impregnation period and by subsequent refining in a 12-in. laboratory disk refiner. The pulp was brightened by sodium peroxide bleaching with negligible reduction in yield. The resulting pulp, designated as No. I (19% lignin), was then delignified with sodium chlorite acidified with acetic acid, which is known to affect primarily the ligneous protion of the pulp. By this chloriting, two pulps designated as Nos. II and III with respectively 12.0 and 2.3% lignin were prepared (Table I).

Fiber Preparation and Sheetmaking

The pulps were refined in a pebble mill according to TAPPI Standard T 224 m-45 and all pulps were beaten to approximately the same four levels of Canadian Standard freeness. The pulps resulting from the different chemical and physical treatments have been coded as shown in Table II. Tappi Standard T 205 m-50 was followed in the sheetmaking procedure, except that the wet pressure was varied. The values of pressure used in separate runs were 0.5, 15, 50, 150, and 960 p.s.i.; these have been designated by the numbers 1, 2, 3, 4, and 5, respectively. Thus, paper sample No. IIC4 designates those handsheets formed from pulp containing 12.0% lignin and beaten to 580 ml. Canadian Standard freeness and that a wet pressure of 150 p.s.i. was applied on the handsheets before drying, Table II. The conditioned sheets were evaluated for thickness, density, and tensile strength (Instron).

Microscopic Techniques

Microscopic investigations of the pulps were conducted with the aid of optical microscopy, both conventional and polarizing. To accentuate the changes in the cell wall produced by delignification, refining, and wet pressing, the fibers were stained with Victoria blue, according to the procedure of Bucher (*17*). This is known to be specific for the identification of the primary wall. Subsequent to staining, the fibers were swollen with a dilute solution of cupriethylenediamine (cuene). Under these conditions the primary wall *P* and the S_1 layer substance remained intact, while the inner layers of the secondary wall expanded. The swollen fibers were then examined with a projection microscope for the degree of swelling, and measurements were made along the fiber surfaces where the outer layers were removed or damaged. The diameters of the normal and cuene treated fibers were determined to assess the extent of swelling.

In some cases, samples of paper embedded in methacrylate, polymerized *in situ*, were sliced with a microtome, without removing the embedding medium. These cross sections of paper were studied under the microscope with respect to changes in fiber shape and degree of fiber packing.

For the preparation of the microtome cross sections, the following technique was applied: paper strips, cut small enough to fit a gelatin capsule, were steeped in acetone for 1 hr. and then transferred into a 50% solution of butyl methacrylate in acetone for one additional hour. Finally the specimens were dipped into pure methacrylate and allowed to stand for another hour. Following this sequence, the strips were fitted into the gelatin capsules, which were then filled with more

Table II. Coding Scheme of Pulps Under Investigation

Sample no.	*Lignin content, %*	*Beating time*		*Can. Standard freeness at 20°C., ml.*	*Wet pressing, pressure, p.s.i.*				
		Min.	*Symbol*		*0.5*	*15*	*50*	*150*	*960*
					Symbols				
I	19.0	0	A	690	1	2	3	4	5
I	19.0	100	B	680	1	2	3	4	5
I	19.0	250	C	590	1	2	3	4	5
I	19.0	500	D	410	1	2	3	4	5
II	12.0	0	A	690	1	2	3	4	5
II	12.0	100	B	680	1	2	3	4	5
II	12.0	305	C	580	1	2	3	4	5
II	12.0	565	D	410	1	2	3	4	5
III	2.3	0	A	660	1	2	3	4	[a]
III	2.3	50	B	640	1	2	3	4	[a]
III	2.3	160	C	590	1	2	3	4	[a]
III	2.3	850	D	370	1	2	3	4	[a]

[a] For pulp III it was not possible to prepare handsheets at the highest wet pressure because of the sticking of the sheets to the blotters and filter papers.

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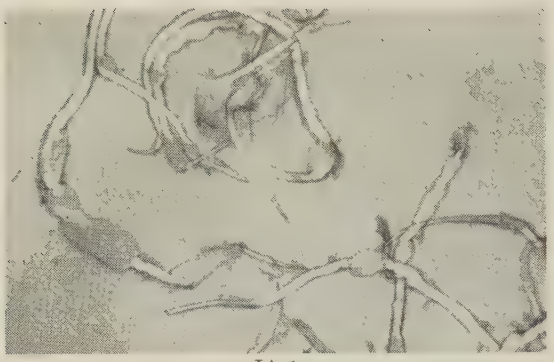
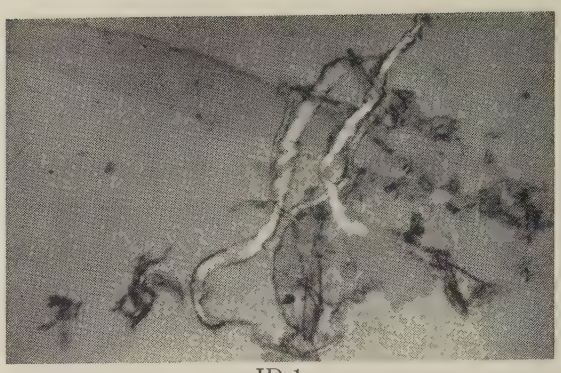


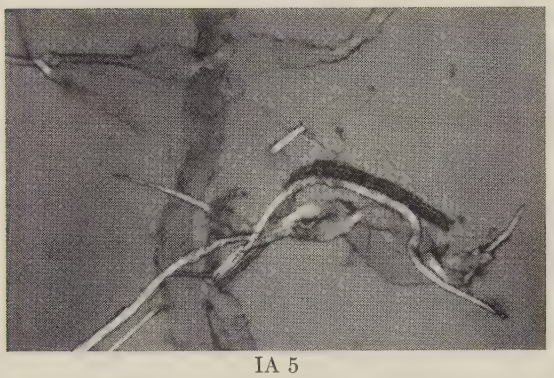
IA 1

Fig. 1. Beating 0 min., freeness 690 ml. Wet-pressing 0.5 p.s.i. 120 ×



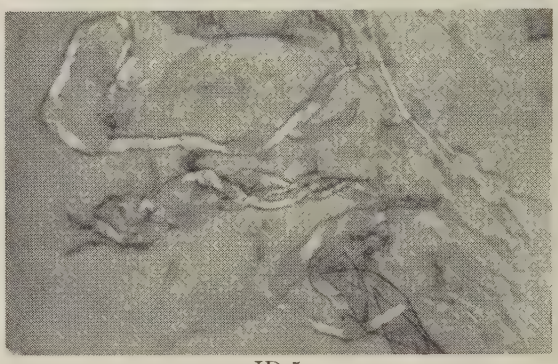
ID 1

Fig. 3. Beating 500 min., freeness 410 ml. Wet-pressing 0.5 p.s.i. 120×



IA 5

Fig. 2. Beating 0 min., freeness 690 ml. Wet-pressing 960 p.s.i. 120×



ID 5

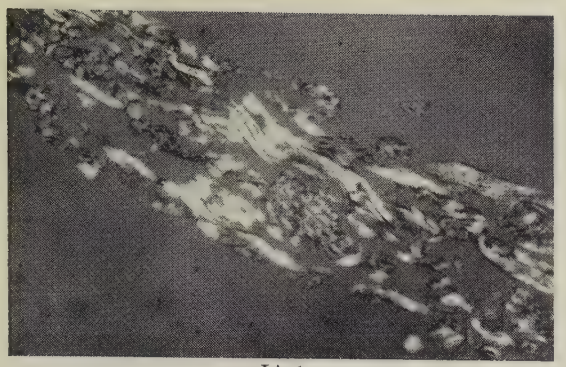
Fig. 4. Beating 500 min., freeness 410 ml. Wet-pressing 960 p.s.i. 120×

Cold Soda Pulps from White Birch, 19% Lignin Fibers Swollen in Cuprietylenediamine

methacrylate. One per cent of benzolyl peroxide was added to the monomer, after it was purified from inhibitors by washing with alkali. The capsules were capped and cured in an oven at 55 to 60°C. for about 12 hr. After cooling, they were steeped in cold water for a few minutes; the softened gelatin was peeled off. The bottom and the sides of the hardened methacrylate rods (in which the paper was embedded) were trimmed off. Sections cut by the microtome were mounted in glycerine on microscope slides.

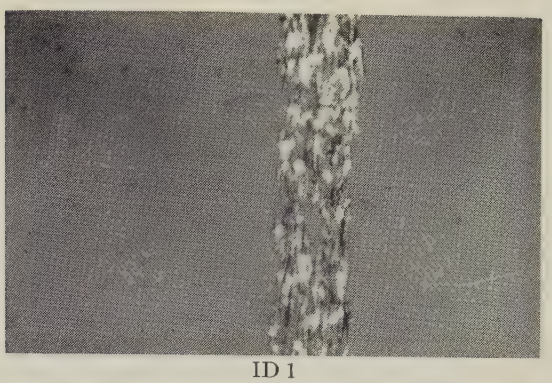
EXPERIMENTAL OBSERVATIONS

Photomicrographs of normal fibers and those treated with cuene were prepared as an aid for studying the changes in fiber structure. It was observed in these plates that beating, in addition to cutting the fiber, rubs off the outer layers of the cell wall. Increasing removal of the P and S_1 layers with increasing beating time was evident. In the early phases of beating, bulky swollen nodes appeared at irregular intervals on the fiber. They originated from the volume increase of the cell wall material at those places, where the removal of the outer layers has occurred. Due to the rigidity of the highly lignified fibers, beating also produced longitudinal splitting and the formation of window-like openings across the fibers. For highly lignified pulps and for unbeaten pulps, increasing degrees of wet pressing induced more splitting of the wall, and many checks perpendicular to the axis of the fibers. In pulps of lower lignin content, however, the cracks in the fiber wall produced by wet pressing were similar in appearance to those obtained in beating. The shape of cell cross sections was seen, as a result of pressing, to change from a circular to an oval outline. For the highly lignified, slightly pressed unbeaten pulp (IA1) the first stage of swelling in cuene appeared as small "pearls" dispersed along the fiber. When the same pulp had been pressed to 960 p.s.i. and swollen, the fibers exhibited big "balloons" with diameters 3 times as wide as those seen at the low wet pressure, Figs. 1 to 4. The effects of mechanical treatment imparted to the rigid, highly lignified fibers were more pronounced than those observed on the delignified fibers. Accordingly, the specimen IA (high lignin, unbeaten) responded only slightly to the swelling action of water or cuene. Nearly the same was found to be true for the No. II series (12% lignin), although the initial stage (IIA1) of cell wall "activation" was more advanced and corresponed to that of the IC1, or IB1 specimens (highly lignified, slightly beaten, slightly pressed). For the pulps delignified to a lignin content comparable to that of unbleached chemical pulp (2.3% lignin), the unbeaten pulps showed very pronounced ballooning and with progressive beating (IIID1), some dissolution of cell wall substance in cuene. The effect of pressing on the cell wall became less distinct in the delignified pulps. With decreasing lignin content the action of cuene was extended over the whole fiber length and the fiber was



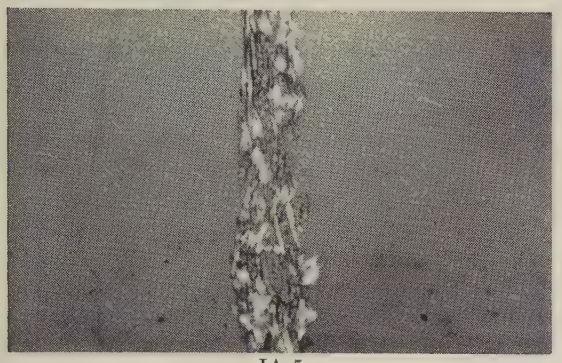
IA 1

Fig. 5. Beating 0 min., freeness 690 ml. Wet-pressing 0.5 p.s.i. 120×



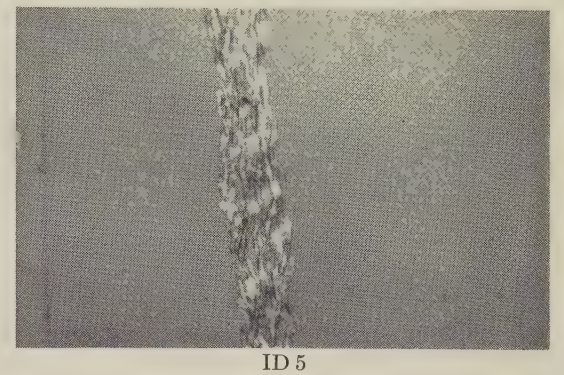
ID 1

Fig. 7. Beating 500 min., freeness 410 ml. Wet-pressing 0.5 p.s.i. 120×



IA 5

Fig. 6. Beating 0 min., freeness 690 ml. Wet-pressing 960 p.s.i. 120×



ID 5

Fig. 8. Beating 500 min., freeness 410 ml. Wet-pressing 960 p.s.i. 120×

Cold Soda Pulps from White Birch, 19% Lignin Cross-Sections of Papers

seen to increase uniformly in volume. The peripheral outline of the fibers was no longer distinct, but appeared to have been dissolved. In the pulps of low lignin content, the lumen disappeared entirely and the cell wall material was greatly expanded.

Microscopic investigations were also made on cross sections of some paper specimens embedded in butyl methacrylate and sliced with the microtome to 5 to 10 mu thick sections. It was observed that in the unbeaten, slightly pressed sample, containing 19% lignin, the fibers were loosely arranged and only small amounts of surfaces were engaged. On fibers oriented in the sections in the z-axis direction, the shape of the fiber cross sections was seen to be round, the lumen open, and the walls intact. Fiber bundles were evident. With progressive beating the outlines of the fibers were no longer smooth but checked and signs of removal of the outer layers could be seen. These exposed parts of the fibers were seen to stick closely to each other and the contacts were more frequent. The outlines of large voids could still be seen in the structure of the paper. Greater compactness (less voids) and increased contact surfaces were obtained by pressing the sheets in the wet condition. With increasing wet pressing the shape of the cross sections of the individual fibers became flatter or oval in shape, and the ends of the ovals were cracked. The lumen space was squeezed to a minimum at the very high wet pressures, Figs. 5 to 8.

Geometrical Data Related to Paper Properties

The extent of removal of P and S_1 layers, as well as "swellability," were measured and related to apparent density and breaking length data of the corresponding paper specimens. These relations are shown graphically in Figs. 9 to 12. It can be observed that the slopes of the curves for the removal of P and S_1 versus density, Fig. 9, as well as for the removal of P and S_1 versus breaking length, Fig. 10, are steeper for increasing wet pressures than for increasing beating time.

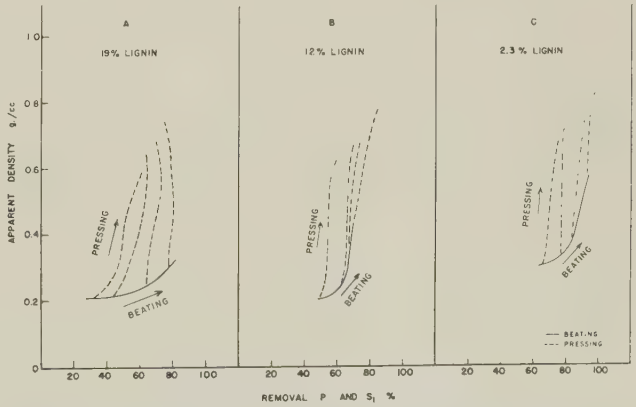


Fig. 9. Relationship between the apparent density and the removal of (P + S_1) layers for increasing degrees of beating, wet pressing, and delignification.

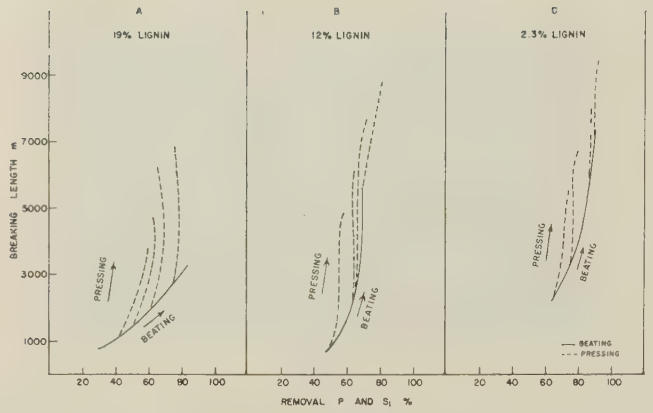


Fig. 10. Relationship between the breaking length and the removal of (P + S_1) layers for increasing degrees of beating, wet pressing, and deliginification

The curves for wet pressing are drawn closer to one another and appear to become more similar to those of beating as the lignin content decreases. Figures 11 and 12 relate the "swellability" of the fiber in cuene with the apparent density and breaking length of the pulps at various degrees of beating, wet pressing, and delignification (Table III). As revealed by the curves,

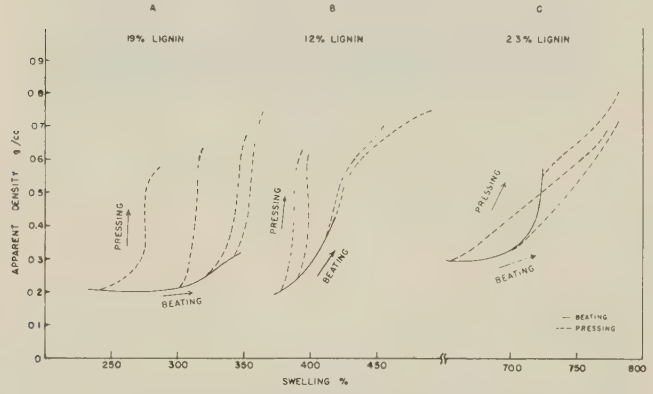


Fig. 11. Relationship between the apparent density and the "swellability" for increasing degrees of beating, wet pressing, and delignification

large changes in density and breaking length occur with relatively small increments in swelling for wet pressing.

Spontaneous densification does not follow with increased "swellability" until sufficient lignin has been removed (specimens II and III). The divergence between the "swellability" effects produced by wet pressing and beating diminishes with decreasing lignin content. As seen in Fig. 12, in all cases at the higher lignin content, wet pressing will increase the density, but at the same time the pulps exhibit no change in "swellability." To induce swelling, the pulp must receive some beating. For the unbeaten, higher lignin content pulps, then, the increased density and breaking length can be produced only through the action of increased wet pressure. For medium lignin contents the increased swelling can be effected by increasing the wet pressure and, as a result, higher values of density and breaking length can be obtained. As seen in Figs. 11 and 12 (A and B) for pulps with 12% lignin the action of pressing on the swelling begins to approximate the effect of beating. After the pulp has been beaten for 500 min., the pressing acts in a manner similar to beating.

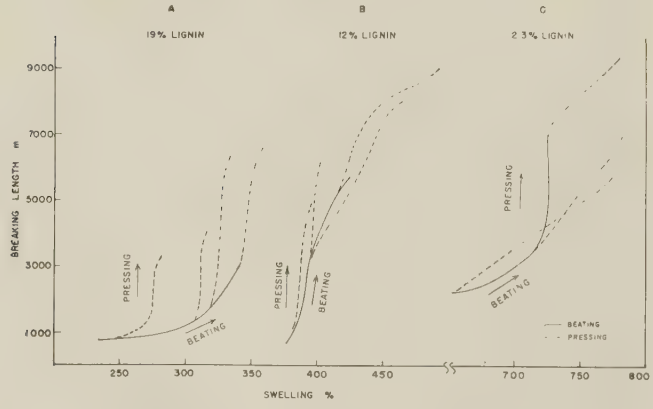


Fig. 12. Relationship between the breaking length and the "swellability" for increasing degrees of beating, wet pressing and delignification

Table III. Apparent Density and Breaking Length Related to Cell Wall Removal and Swellability for Different Degrees of Delignification, Beating, and Wet Pressing

Sample no.	P *and* S_1 *removal,* %	*Diameter ratio, swollen:unswollen*	*Apparent density, g./cc.*	*Breaking length, m.*
	1. 0.5 p.s.i. Wet Pressure			
IA	31.1	239	0.202	730
IB	49.0	307	0.219	1280
IC	64.0	317	0.245	2130
ID	78.4	342	0.303	2950
IIA	51.0	382	0.204	990
IIB	63.7	391	0.243	2040
IIC	62.7	395	0.306	3430
IID	68.2	419	0.405	5450
IIIA	66.3	655	0.301	2300
IIIB	76.8	715	0.339	3570
IIIC	81.6	..	0.387	4240
IIID	>90	725	0.555	7300
	2. 15 p.s.i. Wet Pressure			
IA	47.0	274	0.295	1350
IC	64.7	340	0.358	2980
ID		346	0.438	4350
IIA	..	385	0.314	1570
IIB	..	397	0.373	2910
IIC	..	433	0.465	4690
	3. 50 p.s.i. Wet Pressure			
IA	50.1	..	0.418	1930
IB	..	342	0.427	2600
IC	..	345	0.460	3790
ID	..	346	0.546	5120
IIA	54.7	386	0.448	2480
IIC	..	432	0.564	5520
IID	..	435	0.624	7460
	4. 150 p.s.i. Wet Pressure			
IA	..	278	0.536	3000
IB	63.0	..	0.522	3390
IC	66.3	357	0.582	5220
IIA	..	389	0.558	3600
IIIA	74.2	770	0.665	5570
IIIB	77.0	774	0.705	6490
IIIC	>90	..	0.720	7110
IIID	>90	780	0.797	9340
	5. 960 p.s.i. Wet Pressure			
IA	59.0	284	0.568	3130
IB	63.0	317	0.627	3950
IC	64.3	332	0.669	5980
ID	77.5	360	0.734	6620
IIA	56.7	395	0.626	4660
IIB	69.0	395	0.671	6090
IIC	68.5	455	0.705	7730
IID	81.0	492	0.748	8820

For low lignin contents, 2.3%, the beating and wet pressing curves show little differentiation between their respective effects. With increasing delignification the fibers can be flexibilized easier through beating or pressing, consequently more surface comes into contact in the paper sheet.

The "swellability" in cuene of an unbeaten, slightly pressed fiber (0.5 p.s.i.) is 1.44 times its original diameter. When beaten for 500 min. in a pebble mill, it expands 3.33 times. The maximum swelling was measured at 2.3% lignin content where the diameter of the cell was seen to increase tenfold. Beyond this point, the material of the cell wall forms an amorphous gel and then total dissolution follows.

SUMMARY

The white birch cold soda plup in this investigation consisted of mostly well-separated whole fibers, a small fraction of fiber elements showing across-the-wall fracture, and very few fiber bundles. The lignified fibers were tubular in shape. Handsheets produced from the unbeaten and undelignified pulp indicated comparatively little strength. Strength was induced by beating and wet pressing with the increments being increased through delignification of the parent pulp.

While all pulps at the three different lignin contents exhibited nearly the same changes in P and S_1 removal with progressive beating, the magnitude of strength development was found to differ greatly. The changes imparted to the cell wall substance through beating were reflected in the swellability of the fibers. The capacity for swelling was increased with increased lignin removal. At the same time greater strength levels were achieved.

Wet pressing had little effect on the removal of P and S_1 layers in all cases. However its application promoted strength development to a significant degree. Its effects, however, varied depending on the product derived from the parent pulp. For the parent pulp, wet pressing of the fibers produced hardly any effect on the swellability of the fibers. Upon removing lignin, and after some beating had been accomplished, wet pressing was observed to produce a change in the fibers similar to that obtained through ball milling.

The findings indicate that the removal of lignin allows the hemicelluloses which these pulps contain in large amounts to swell more freely. As a result the fibers become more flexible and pack into denser sheet. The strength potential is thereby increased.

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The Network and Viscoelastic Properties of Wet Pulp

I. Dynamic Mechanical Properties

SHELDON F. KURATH

The network and viscoelastic properties of a southern pine bleached kraft pulp have been investigated in considerable detail. Real and imaginary components of the complex shear modulus as well as the normal stress necessary to compact the pulp have been studied as a function of pad concentration. Both the complex shear modulus, defined as the ratio of sinusoidal stress to sinusoidal strain, and the normal stress depend on pad concentration in a similar manner. This similarity has been used as a basis to define a generalized function, $Q(n, f)$, which is intended to be a measure of internal changes within the pad resulting from changes in interfiber contacts and forces acting at the contact points. Compression was found to have no effect on the general frequency dependence of the complex shear modulus within the 6 to 1000 c.p.s. frequency range. A reference complex shear modulus, G_0^*, is obtained and its possible use as an index to fiber flexibility is indicated. The general features of a rheological equation for wet pulp are discussed.

The rheological behavior of wet pulp is dependent on the viscoelastic properties of the wood fiber and the character of the network structure that is formed as a result of fiber-to-fiber contact. Ultimately it would be desirable to establish a rheological "equation of state" for the fiber water system. Such an equation

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would be extremely useful both as a means of characterizing pulp and as a basis for industrial equipment design. The task of establishing such an equation would be simplified considerably if effects due to the viscoelastic properties of the fibers could be separated from the properties inherent in the fiber network structure. The present work represents an attempt to study the viscoelastic and network properties of wet pulp and to determine the general form of a rheological equation of state for wet pulp.

NOMENCLATURE

A	=	sample area, sq. cm.
C_p	=	pad concentration, g. per cu. cm.
$G^*(j\omega)$	=	complex shear modulus, dyne per sq. cm.
$G'(\omega)$	=	real component of the complex shear modulus, dyne per sq. cm.
$G''(\omega)$	=	imaginary component of the complex shear modulus, dyne per sq. cm.
M, N	=	constants
$M(t)$	=	time dependent viscoelastic function
M_0	=	a modulus in an arbitrary reference state
P	=	normal stress, dyne per sq. cm.
$Q(n, f)$	=	reduction factor, unitless
f	=	forces acting at fiber to fiber contact points
h	=	sample thickness, cm.
j	=	$\sqrt{-1}$
n	=	number of fiber to fiber contacts
t	=	time
w	=	weight of dry fiber
$tan\ \delta$	=	G'/G'' = mechanical loss tangent
$\eta'(\omega)$	=	dynamic viscosity, poise
ν	=	frequency, c.p.s.
σ	=	stress, dyne per sq. cm.
τ	=	relaxation time
ω	=	circular frequency, $2\pi\nu$

BACKGROUND

When a dilute pulp suspension is filtered either in a sheet mold or in a specially designed filtration apparatus, a pad of pulp may be formed having a low solids content. If a normal stress is applied to the wet pad, it is possible to study the solids content as a function of stress. Such "compressibility" experiments have been carried out in considerable detail (*1*) and the normal stress and solids content of the pad are found to be related by means of a definite empirical expression. It is generally observed that,

$$N \log P + \log M = \log C_p \qquad (1)$$

where P is the normal or compacting stress on the pad in dynes per sq. cm., C_p is the pad concentration in grams of oven-dried fiber per cu. cm., and N and M are constants which depend on the nature of the pulp.

If the pad were composed of ideal fibers with mechanical properties that do not change with stress or time, the empirical expression would be an index to internal changes within the pad. That is, the expression would be a measure of the number of fiber-to-fiber contacts, the forces exerted at the contact points, and would indicate how both of these change with pad compression.

One property of such an idealized fiber network is that the shear modulus (based on the apparent pad dimensions) should obey the same empirical laws as the normal stress when both are expressed as a function of pad concentration. Through proper interpretation of these expressions for normal stress and shear modulus, it is possible to establish a general empirical expression which is characteristic of changes in internal pad structure.

When an applied stress causes molecular or atomic changes within a solid, the changes are observed over many decades in the experimental time scale and the material is said to be viscoelastic. This is particularly true of crystalline polymeric materials such as cellulose where the stress-induced motion of the polymer chains is at best a lengthy process. It is for this reason that considerable time and effort has been expended in studying the mechanical properties of crystalline polymers over wide ranges in experimental time.

A number of investigators have examined the time-dependent mechanical properties of paper. The creep properties of paper have been extensively investigated for times longer than 10 sec. (*2*). Sonic resonance (*3, 4*) and a torsion pendulum (*4*) are among the dynamic techniques employed. In addition, a vibrating reed technique has been used to examine the Young's modulus of paper in the 20 to 180 c.p.s. frequency range (*5*).

The viscoelastic properties of wet swollen pulp have received less attention. There are, however, several investigations on the creep of wet pulp in compression (*1, 6*).

Among the more important techniques for investigating the time dependent modulus of a material is the use of the double electromagnetic transducer (*7*). This investigative tool makes it possible to examine the dynamic shear modulus of a material over a continuous frequency range. In addition, proper interpretation of the dynamic shear modulus makes it possible to obtain information that cannot be obtained from standard testing procedures of the stress-strain type. This technique was preferred in the present investigation.

EXPERIMENTAL TECHNIQUES

The Double Electromagnetic Transducer

If a sinusoidal stress $\sigma = \sigma_0 \sin 2\pi\nu t$ is applied to a viscoelastic object such as a pad of wet swollen pulp, a sinusoidal strain will be observed which is out of phase with the applied stress. It is customary to speak of the ratio of stress to strain as the modulus. This can also be done in the present case if stress and strain are replaced by their corresponding sinusoidal quantities. If the strain is a shear strain, the modulus will be the complex shear modulus, $G^*(j\omega)$, and is given by

$$\frac{\text{Stress}}{\text{Strain}} = G^*(j\omega) = G'(\omega) + jG''(\omega) \qquad (2)$$

where $G'(\omega)$ is the real or "solid like" component of the complex shear modulus, $G''(\omega)$ is the imaginary or "liquid like" component, and ω is the circular frequency. This means of representing the modulus has an advantage over the more commonly used static modulus in that it reveals solid and liquid behavior as components of the complex modulus. The liquid nature of $G''(\omega)$ is easily seen by writing this as

$$G''(\omega) = \omega\eta'(\omega) \qquad (3)$$

where $\eta'(\omega)$ is the dynamic viscosity.

Another extremely useful relationship is the mechanical loss tangent, $\tan\ \delta = G''(\omega)/G'(\omega)$, since it is related to energy stored and energy lost per cycle, i.e.,

$$\frac{\text{Energy lost per cycle}}{\text{Energy stored per cycle}} = \pi \frac{G''(\omega)}{G'(\omega)}. \qquad (4)$$

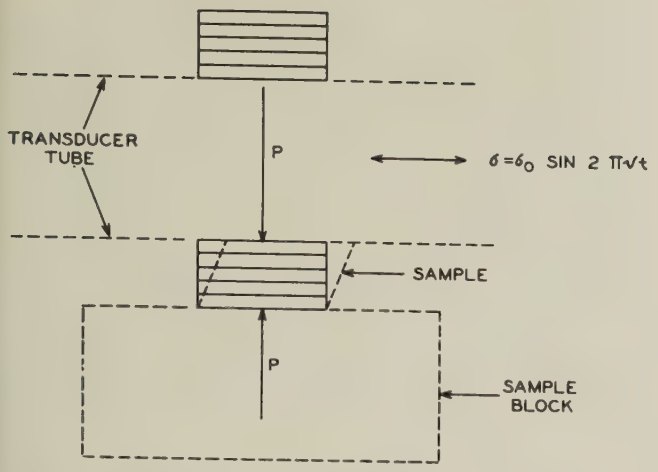

Fig. 1. Schematic diagram of the electromagnetic transducer showing the normal and shearing stress on a typical pulp sample

The complex shear modulus of a material may be conveniently determined by means of the electromagnetic transducer, of which a complete discussion is given elsewhere (*7*). The instrument consists of a light aluminum tube which is fitted at each end with coils of copper wire. Each coil is placed in the radial field of a permanent magnet. Pulp samples are sheared between the tube and two heavy sample blocks when an alternating current is supplied to the coils. The sample is subjected to a complex loading and both normal and shear stresses are present (Fig. 1). By measuring the real and imaginary components of the electrical transfer admittance it is possible to obtain the complex shear modulus of the pulp.

Sample Preparation

The pulp used in these experiments was a sample of southern pine bleached kraft. Pertinent physical characteristics of this pulp are presented in Table III.

All pulp used in these experiments was prepared in the following manner. The dry pulp lap was torn into small pieces and soaked overnight in water at room temperature. The wet lap was then dispersed at 0.4% consistency in a British disintegrator for approximately 15,000 revolutions (600 counts). Pulp sheets were prepared using a Valley sheet mold and a forming consistency of 0.1%. The sheets were maintained in a wet condition and were transferred to aluminum foil for subsequent handling. The transfer was accomplished by supporting the pulp sheets by means of wide spatulas since they would not support their own weight.

Disk-shaped specimens were then cut from the wet pulp by means of a circular arch punch. These were then stacked upon one another to form a pad of a thickness suitable for transducer measurement. The pads were then immersed in water and stored in this condition until they were used.

RESULTS OF DYNAMIC MEASUREMENTS

Complex Shear Modulus

The complex shear modulus, $G^*(j\omega)$, of the sample pad was computed on the basis of the actual area and thickness. Samples were easily compressed and it was possible to determine the shear modulus as a function of compression. For convenience, the degree of compression is expressed in terms of pad concentration,

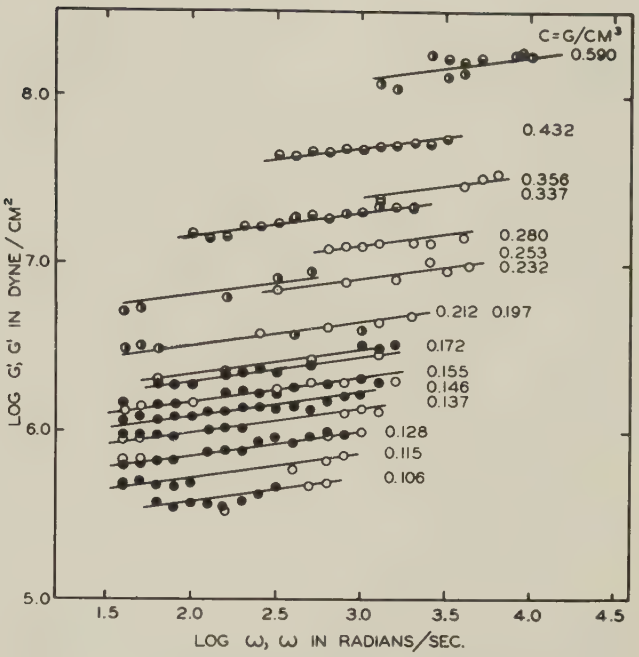

Fig. 2. Real component of the complex shear modulus for a southern pine bleached kraft pulp; black, white, bottom black, and right black points refer to four different sample sets

$C_p = w/Ah$, where w is the weight of dry fiber in the pad (after drying to constant weight at 105°C.) and A and h are the area and thickness of the wet pad, respectively. All instrument measurements were performed while the sample was wet and water was continuously dropped on the sample to insure this condition.

Real $G'(\omega)$ and imaginary $G''(\omega)$ components of the complex shear modulus are shown in Figs. 2 and 3 as a function of frequency, and at 15 pad concentrations ranging from 0.106 to 0.590 g. per cu. cm. The measurements are the results of experiments carried out on four sets of sample pairs (eight samples in all).

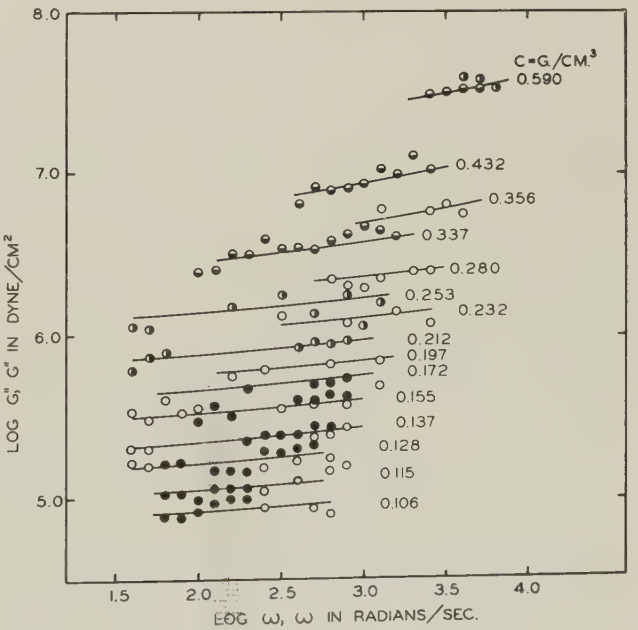

Fig. 3. Imaginary component of the complex shear modulus for a southern pine bleached kraft pulp; black, white, bottom black, and right black data points refer to four different sample sets

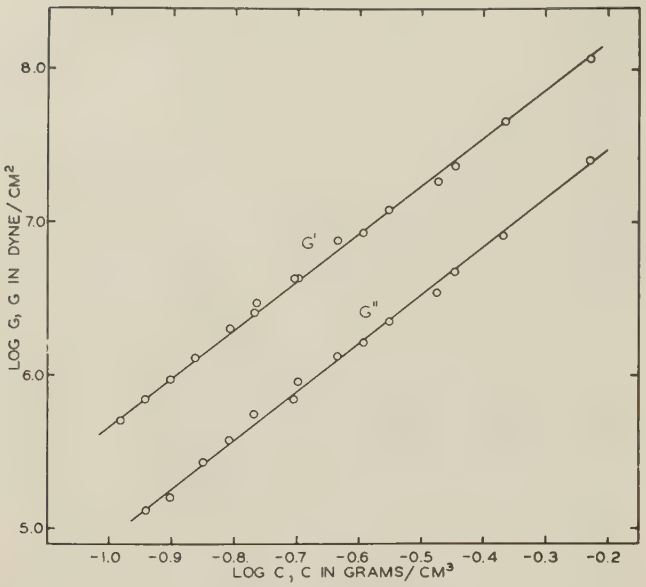

Fig. 4. Real and imaginary components of the complex shear modulus as a function of pad concentration for a southern pine bleached kraft pulp; the components of the complex shear modulus are given at a constant frequency of 100 c.p.s. (log ω = 2.8)

It is apparent that pad concentration has little or no effect on the general frequency behavior of $G'(\omega)$ and $G''(\omega)$ within the frequency range covered by these experiments, 6 to 1000 c.p.s. It is also worth while to examine the manner in which $G'(\omega)$ and $G''(\omega)$ depend on pad concentration. Real and imaginary components of the complex shear modulus were determined from Figs. 2 and 3 at a constant frequency ν of 100 c.p.s. (log ω = 2.8). This is shown in Fig. 4. Within the range of the present measurements, it appears that the log of the complex shear modulus is a linear function of the log of the pad concentration. This can most easily be expressed as

$$N \log G^* + \log M^* = \log C_p \qquad (5)$$

or in component form as,

$$\begin{aligned} N \log G' + \log M'' &= \log C_p \\ N \log G'' + \log M'' &= \log C_p \end{aligned} \qquad (6)$$

Values of these physical constants are given in Table I, Part A. It should be noted that a single value for the constant N applies for both equations involving G' and G''. This means that the mechanical loss tangent, $\pi G''/G'$, is independent of pad concentration.

Some Important Factors Concerning the Dynamic Measurements

There are several important factors that need to be considered at this point. The first question that arises is one involving the complex mechanical loading to which the pad is subjected. In addition to the sinusoidal shear stress applied by the transducer there is a stress, P, of considerable magnitude normal to the plane of shear, as shown in Fig. 1. Since the pulp mats are viscoelastic and, therefore, subject to stress relaxation normal to the plane of shear, it is necessary to determine whether or not this normal relaxation has any effect upon the magnitude of the complex shear modulus. This effect was investigated in considerable detail both by means of the transducer and by direct study of the normal stress itself. Below a pad concentration C_p of 0.318 (log C_p = −0.5), both the normal stress and the complex shear modulus were slightly time dependent. Changes during the time that transducer measurements were taken were, in general, less than 3%. Measurements at a given pad concentration were taken at least 5 to 10 min. after the normal stress was applied and were in general completed 40 min. after initial compression.

At higher pad concentrations than C_p of 0.318 g. per cu. cm., there is a considerable relaxation of stress normal to the plane of shear. This was difficult to study on the transducer but was studied in some detail by means of a stress relaxation experiment. A discussion of this particular experiment is given in the following section.

Another point of concern arises in regard to the effect that the flow of water within the sample has upon the properties of the wet swollen fibers. This water flow will be apparent as a viscous effect and as such would be expected to make a contribution to the imaginary component of the shear modulus since this contains the dynamic viscosity of the sample. Two extreme cases may be considered. In Case I the viscous effect of water flow through the pad is greater than the viscosity due to the motion of the segments of the plasticized cellulose chains which make up the fiber. For Case II the viscosity due to cellulose chain motion is predominant. The basis for a choice between these two cases lies in the experimental fact that the mechanical loss tangent, $G''/G' = \omega\eta'/G'$, does not depend on pad concentration. If the viscous flow of water through the pad were important, one would expect G'' to have a considerably different dependence on pad concentration than G'. This difference, however, is not observed and it may be concluded that the flow of water through the pad is not influencing the mechanical behavior of the pad.

A similar conclusion may be drawn from the following evidence: If Case I were valid and the viscous flow of water were important, the following reasoning would be valid. The viscosity of water is essentially independent of frequency so that $\eta'(\omega)$ should not depend on frequency in this case. Since $G'' = \omega\eta'(\omega)$, the value of G'' should increase directly with ω. On the logarithmic curves of Fig. 2, G'' vs. ω curves should yield straight lines with slopes of +1. This also is not observed.

The question now arises as to what effect different basis weights of the individual plies of the sample might have on the observed mechanical properties of the pulp. Experiments were carried out by preparing pads made up of plies having ovendry weights of 0.0060, 0.0148, 0.01994, and 0.0843 g. per sq. cm. Measurements of G' and G'' were taken at a constant frequency of 100 c.p.s. The data for all three basis weights could be superimposed upon the curve of Fig. 4 within experimental error indicating that these measurements are essentially independent of the ply thickness.

"Compressibility" measurements were carried out in order to determine the magnitude of the normal stress in the sample subject to dynamic measurement. Samples of pulp were prepared in the same manner as those used in the dynamic measurements. At low pad concentrations the normal stress was determined by a creep experiment. The sample pads were subjected to a normal stress, P, and the pad concentration was determined

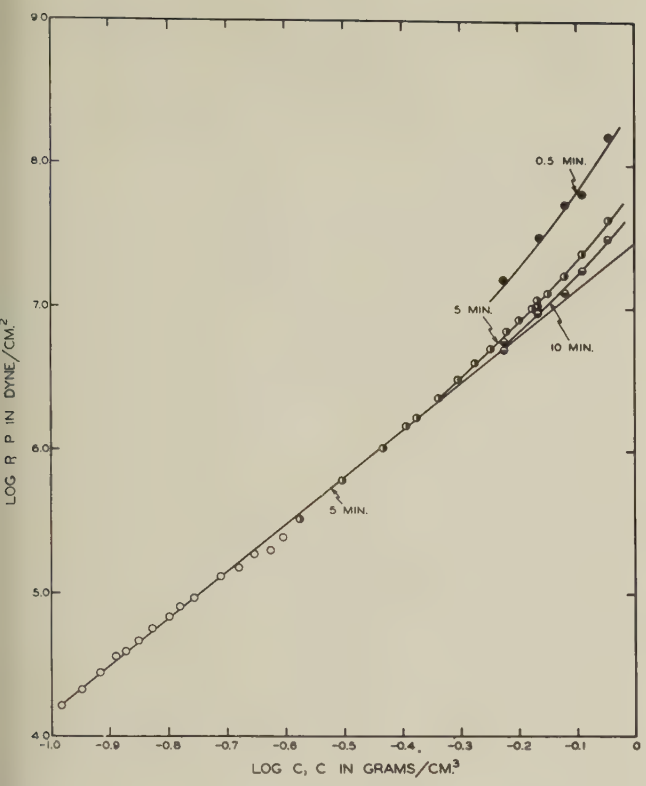

Fig. 5. Results of a normal stress ("compressibility") experiment on a southern pine bleached kraft pulp; open points are the results of a creep study and the shaded points are for stress relaxation

after 5 min. At higher pad concentrations the samples were studied in a stress relaxation experiment. The samples were compressed and held at constant strain in a Baldwin Southwark Universal Tester. The relaxation of stress was observed as a function of time.

The results of these "compressibility" measurements are shown in Fig. 5 where the normal stress is given as a function of pad concentration. At high pad concentrations the measurements were found to be quite time dependent as indicated by the results at different time intervals. At the highest pad concentration, a fivefold difference in P is observed between 30 sec. and 10 min.

At low pad concentrations, log P is a linear function of log C_p as expected from the general validity of equation (1). The constants for this relation were evaluated and are given in Table I, Part B. The values of N obtained by transducer measurement and by normal stress studies are in approximate agreement for the pulp experiments reported here.

At pad concentrations greater than a C_p of 0.318 g. per cu. cm. ($\log C_p = -0.5$), there is considerable stress relaxation. This was studied in some detail. For times greater than 5 min. after sample compression, the stress decay was that of a simple viscoelastic Maxwell element (*8*), and accordingly the stress decay was governed by the relation,

$$P = P_{t0}e^{-t/\tau} \qquad (7)$$

Table I. Physical Constants for Southern Pine Bleached Kraft Pulp

Part A: Constants for the Relation,

$$N \log G^* + \log M^* = \log C_p$$

At a Frequency of 100 c.p.s. ($\log \omega = 2.8$)

Component of G, dyne/cm.²*	*M**	*N*
G'	$M' = 0.00154$	0.319
G''	$M'' = 0.00263$	0.321

Part B: "Compressibility" Constants for the Relation,

$$N \log P + \log M = \log C_p$$

Normal stress, P	*M*	*N*
P, dyne/cm.²	0.00555	0.302

P is the normal stress at time t, P_{t0} is the stress at time $t = 0$, and τ is the characteristic relaxation time. The relaxation time decreases with increasing pad concentration as indicated by the values given in Table II. This information will be used to convert the normal stress measurements to the same time scale as the dynamic experiments.

Table II. Characteristic Relaxation Times for the Stress Relaxation of a Southern Pine Bleached Kraft Pulp

Pad concentration, C_p, in g./cm.³	*Log C_p*	*Relaxation time, τ min.*
0.595	−0.225	36
0.683	−0.165	31
0.760	−0.120	18
0.812	−0.090	18
0.904	−0.044	17

GENERALIZED FACTORS

There are several features apparent in the results of the dynamic measurements that would seem to permit generalization. The fact that the frequency dependence of the complex shear modulus is unaltered by compression, coupled with the fact that the mechanical loss tangent is likewise compression independent, indicates that no marked changes are taking place in the inherent nature of the cellulose-water system.

What seems to be important in determining the effect of pad concentration of the mechanical properties is the manner in which interfiber forces and interfiber contacts change with compression. If the pulp pads are viewed as a complex system of multiply loaded beams that are stacked at random, then the load necessary

Table III. Physical Characteristics of Southern Pine Bleached Kraft Pulp

Refining time, min.	*Basis weight*	*Caliper, mils*	*Apparent density*	*Burst*	*Tear factor*	*Corrected tensile strength, lb./in./45 lb.*	*Corrected zero-span tensile strength, lb./in./10 lb.*
0	46.7	4.6	10.2	25	2.14	5.06	19.7
5	46.3	4.1	11.3	49	1.79	7.44	21.2
20	46.3	3.5	13.2	91	1.14	13.3	22.7
35	45.8	3.3	13.9	103	0.96	16.5	24.9
50	45.7	3.1	14.7	114	0.85	18.0	25.6
65	65.4	3.0	15.1	126	0.84	18.9	25.8
80	46.6	2.9	16.1	176	0.75	19.8	26.9

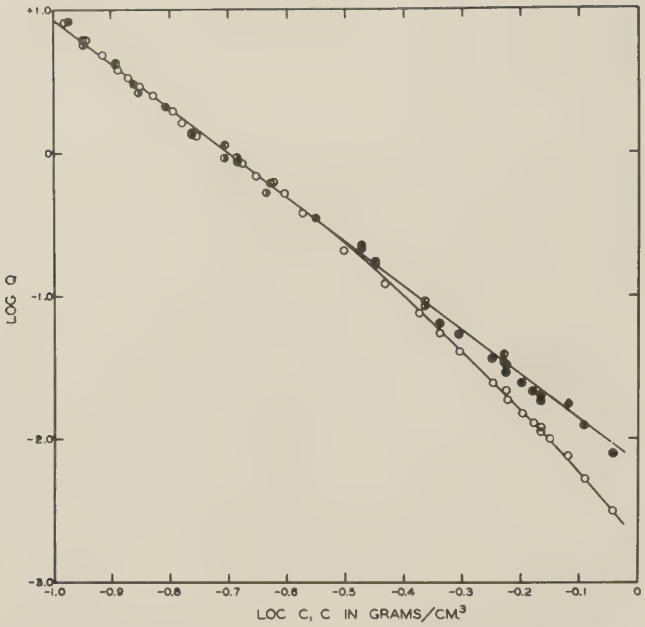

Fig. 6. Reduction factors for real and imaginary components of the complex shear modulus and for the normal stress; right and left-shaded points are from normal stress measurements taken at 5 min.; solid points are normal stress measurements corrected to the same experimental time scale as the complex shear modulus

to compact the system would depend on the number of initial fiber-to-fiber contacts, the force necessary to deflect the fibers and forces due to the development of new contact points between fibers. This picture is not as crude as it might seem since no assumption is made regarding uniformities in fiber length, cross section, or stiffness.

If this type of network structure represents a true picture of the compression process, then it should be possible to write the normal stress and the complex shear modulus $G^*(j\omega)$ in the following forms,

$$\begin{aligned} Q(n, f)P &= P_0 \\ Q(n, f)G^*(j\omega) &= G^*(j\omega)_0 \end{aligned} \qquad (8)$$

where P_0 is the normal stress and $G^*(j\omega)_0$ is the complex shear modulus at an arbitrary reference pad concentration. The function $Q(n, f)$ is the same for both equations and is intended to be a function of only n, the number of fiber-to-fiber contacts, and f, the force at a given contact point. Both n and f are functions of pad concentration.

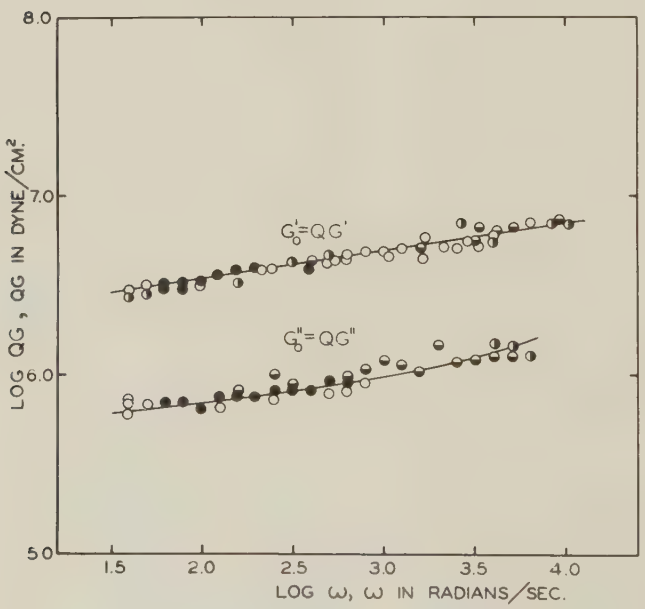

Fig. 7. Reduced curves for the complex shear modulus of a southern pine bleached kraft pulp at a reference pad concentration, C_p, of 0.200 g. per cu. cm.

The results of applying this reasoning to the data at hand is shown in Figs. 6 and 7. An arbitrary reference pad concentration, $C_{p,0}$, of 0.200 g. per cu. cm., was chosen as a reference. The value of P_0 at this concentration is $P_0 = 1.29 \times 10^5$ dyne per sq. cm. The corresponding real and imaginary components of the complex shear modulus are a G'_0, of 4.26×10^6 dyne per sq. cm. and G''_0, of 8.10×10^5 dyne per sq. cm. at a frequency of 100 c.p.s.

The values of $Q(n, f)$ necessary to reduce all values of P and $G^*(j\omega)$ to the reference concentration, $C_{p,0}$, are shown in Fig. 6. At pad concentrations less than C_p of 0.318 g. per cu. cm. ($\log C_p = -0.5$) there is good agreement between $Q(n, f)$ values determined from dynamic data and from compressibility measurements. At higher pad concentrations the normal stress and dynamic values differ in $Q(n, f)$. The reason for this difference is due to differences in the time scales of the two experiments. The compression experiments are given 5 min. after compressing the pad and the average time to carry out transducer measurements at high pad concentrations was of the order of 20 min. The relaxation time data of Table II were used to correct the normal stress measurments to the 20-min. time scale. When this is done, it is seen that there is good agreement between the two types of experiment. This seems to justify the use of $Q(n, f)$ as a network parameter involving changes in interfiber forces and contacts.

By reducing the complex shear modulus by the factor $Q(n, f)$ it is possible to describe the general frequency behavior of the pulp between 6 and 1000 c.p.s. The curves of Fig. 7 were obtained in the course of evaluating $Q(n, f)$. The absolute magnitude of QG' and QG'' depend on the nature of the pulp and in general are expected to be different for different pulps.

DISCUSSION

The use of the $Q(n, f)$ reduction or network factor has several advantages. It permits generalization of the biaxial properties of the wet pulp. When used in conjunction with the frequency dependent shear modulus it provides a characterization of the viscoelastic behavior of the pulp. The reduced complex shear modulus $G^*(j\omega)_0$ should be a useful index to fiber flexibility since both the absolute magnitude and frequency dependence of this quantity should depend on flexibility. Additional experiments on a bleached sulphite and an unbleached kraft pulp have indicated that this may be a useful means of determining fiber flexibility.

The fact that stress does not alter the frequency dependence of the complex shear modulus is most interesting. From a rheological viewpoint the wet pulp should follow a type of modified Boltzman superposition principle involving pad concentration, stress, and time. As a result, it is possible to speak in terms of a general rheological equation of state for wet pulp. It will probably take the following form,

$$C_p = Q(n, f) \cdot M(t) \cdot M_0$$

where $Q(n, f)$ is the network factor, $M(t)$ is a time dependent function characteristic of the viscoelastic properties of the individual fiber, and M_0 is an apparent modulus (or stress) at some arbitrary reference pad concentration, C_{p0}.

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Wet-Web Strength of Mechanical and Chemical Pulps of Different Form Composition

W. BRECHT and H. ERFURT

A new testing device which determines the stress-strain properties of paper in the range of water contents of practical importance (13–90% solids) has been developed. The description of the method and of its range of measurement precedes the report of some investigations, with which the tensile strength of various fibrous materials has been measured for the entire process of dewatering. The results show that the wet-web strength of paper during drying (free shrinkage) follows an exponential function with respect to dry content; the wet-web strength depends at high water contents on friction between fibers, but at low water contents on interfiber bonds. The influence of beating and of fiber swelling on wet-web strength is described and discussed. Special attention was paid to the form components of groundwood and chemical pulp and the role they are playing for wet-web strength and to the surprisingly simple laws concerning the relationship between the content of fines and wet-web strength.

It is a great pleasure for us to be able to report on our recent findings pertaining to the subject: "Wet-Web Strength of Mechanical and Chemical Pulps of Different Form Composition," since, in America, great strides have been made in the technical and scientific measurement of wet-web strength. Particularly enlightening are the studies of Logan (*1*) and De Montigny (*2*), concerning the wet bursting strength, and the investigations of Andrews, Bledsoe, and Collicut (*3*), Langins (*4*), McCallum (*5*), Forgacs, Robertson, and Mason (*6*), and especially those of Lyne and Gallay (*7–9*). In spite of this excellent research work and although experimental work on wet-web strength has also been carried out in Europe by Brecht and co-workers (*10–14*), Schröter (*15*), Gavelin and Forsberg (*16*), Anderson and Bergstrom (*17*), Nordman and Eravuo (*18*), and Ullman (*19*), many important questions are still unanswered. There is still little known on how the nature of the various pulps and the properties of the form components, the long and short fibers, the fines, etc., affect the wet-web strength. Nor is it known what significance fiber swelling and beating have on the tensile properties of the wet web. Furthermore, there is, as yet, no *single* apparatus which provides full information on the stress-strain properties of paper for the whole range from the wet to the dry state, as well as over the influence of the test conditions.

However, there exist, at present, a number of instruments which, in principle, would enable us to measure the stress-strain relations of paper in the range of dry contents of practical importance, that is from the wet to the air-dry state (*20–23*). Practically all these instruments employ electronic measuring units and operate with constant rate of straining. However, in spite of the fact that they are very expensive, their precision of measurement in testing wet webs is not completely satisfactory, either because of the vertical clamping of the sample, or because of the comparatively large deflection of the stress gage. Those instruments in which the rate of loading is constant, normally do not measure the actual stress *in* the paper sample, but rather the *externally* applied, steadily increasing load. They are unable to measure decreasing loads and, therefore, they cannot detect and determine the strain at the breaking point.

A NEW STRESS-STRAIN MEASURING INSTRUMENT

To overcome the foregoing deficiencies of existing apparatus, a new wet-web tester has been developed. It strains the specimen at constant rate and is suitable for studying the rheological properties of paper over a large range of dry contents, namely from 12% ovendry to air dryness. In addition, it permits wide variation of testing conditions.

This instrument is a rather complicated apparatus which measures the tensile strength and the elongation at the breaking point, while simultaneously recording the stress-strain relation over the entire range of meas-

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urement. Since this apparatus is designed for determinations on wet and dry papers, it is necessary that its range of measurement be very broad and that it has high precision and accuracy over the entire range. Because of the limitation of space, the apparatus cannot be described in detail.

Figure 1 is a schematic diagram of the apparatus as seen from above. The upper diagram shows the ar-

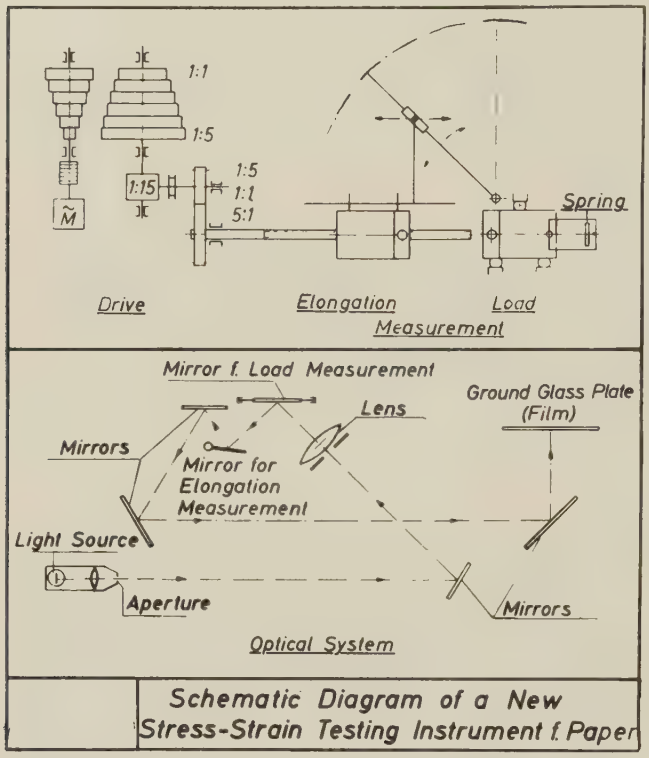


Fig. 1

rangement of the load and elongation recording devices. The straining device comprises a three-phase electric motor, a variable gear assembly, and a threaded shaft which, when rotated, draws the left-hand paper clamp at constant rate. Thereby, the horizontally clamped paper strip is strained. The stress related to this strain is transmitted through the right-hand clamp, mounted on ball bearings, to a highly sensitive leaf spring.

The stress-strain diagram is automatically recorded with the aid of an optical system. For the measurement of load and elongation movable mirrors are used—one horizontal and one vertical. The linear movement of the left-hand clamp is converted into an angular deflection of the vertically mounted mirror for strain measurement, while the horizontal mirror undergoes a deflection corresponding to the load acting upon the leaf spring.

The optical system is depicted in the lower diagram of Fig. 1. Light passing through a small aperture and a condenser lens is projected as a small point upon the ground-glass plate. In the path of the light are also the movable mirrors for measuring load and elongation as well as a number of fixed mirrors. The load-elongation curve resulting from the simultaneous movement of the two movable mirrors projecting the light point, can be either instantaneously observed with the eye or permanently recorded on highly sensitive silver bromide paper.

It should be mentioned that the constant rate of straining can be increased 400 times from 0.08 to 32 in. per min. Loads from 30 to 15,000 g. and elongations from 0.004 to 0.75 in. can be measured. The clamps which allow testing of samples up to 2 in. in width can be separated up to 4 in.

The investigations were carried out on samples which have been produced on a sheet machine using the German Standard method (*24*). A special frame was used in the preparation of the handsheets, which allowed the immediate formation of the sample strips, thus avoiding the problems arising when attempting to cut a wet sheet. The sheets were first dewatered by moderate suction and then with the aid of blotters. At no time was heat used. During this dewatering process the sample was subjected to a very low pressure so that shrinkage could occur practically unrestrained. In this way an almost constant dry content was obtained on each point of the strip, which is the basis for reliable and precise measurements.

The paper strips were fastened in special clamps, so that in testing even very wet webs as little water as possible was pressed out of the specimen. In order to prevent evaporation of water from moist samples, the paper was enclosed in a conditioning chamber, in which a high relative humidity could be quickly attained.

The following conditions were held during tests:

Basis weight	75 g. per sq. in.
Sample width	$1\frac{1}{4}$ in.
Gap between clamps	4 in.
Rate of straining	0.78 in. per min.

STRESS-STRAIN PROPERTIES OF WET WEBS AND DRY PAPERS

Before reviewing the results of the experiments, it should be briefly mentioned that the rheological properties of very wet webs are, in principle, similar

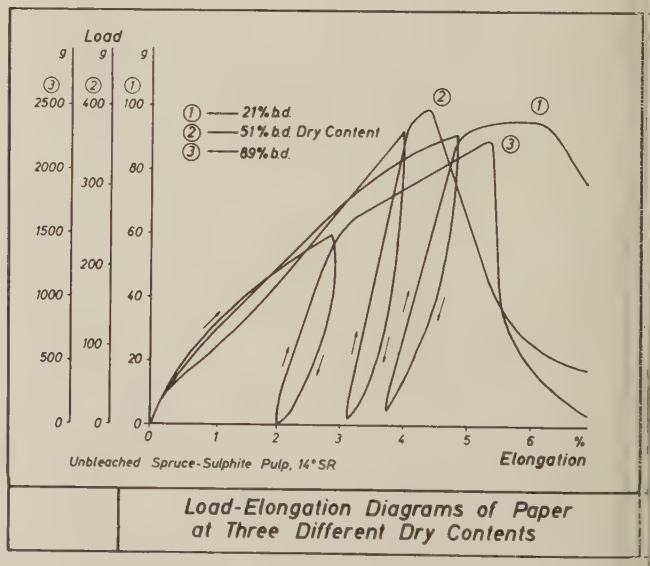
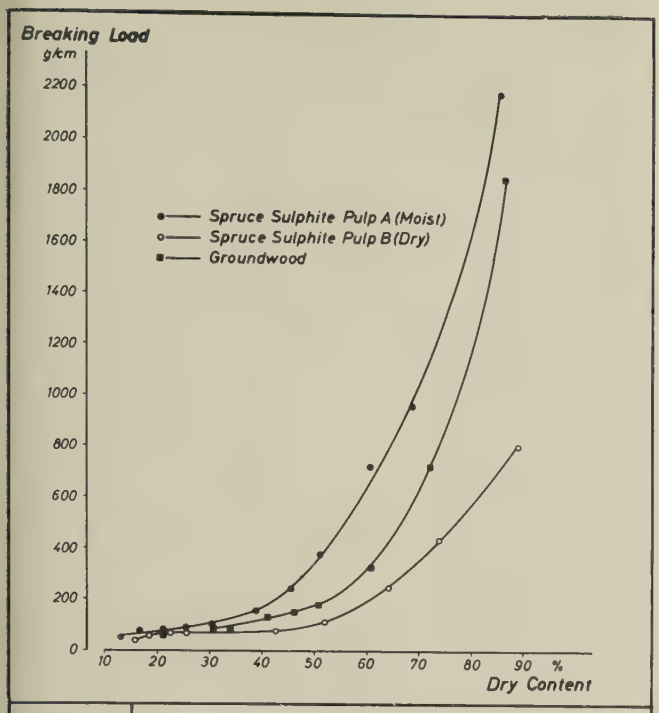


Fig. 2

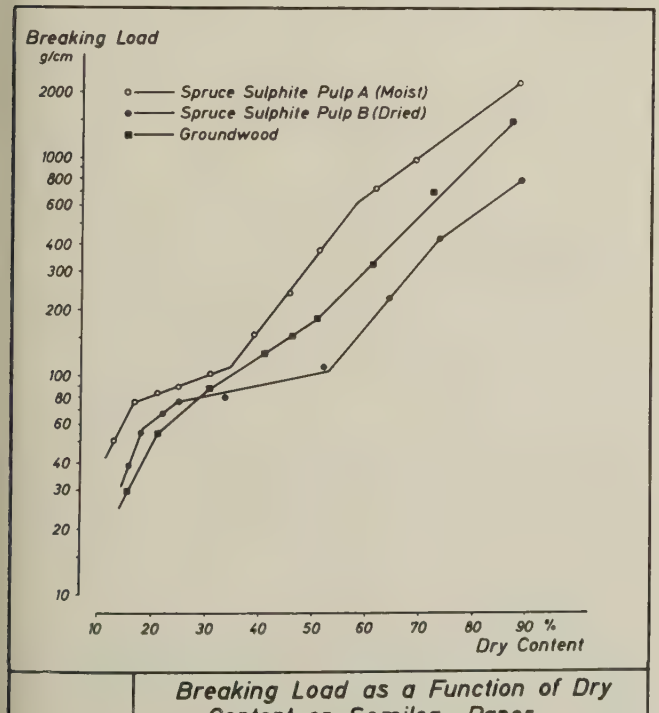
to those of dry papers, as first pointed out by Brecht and Volk (*13*) and, at about the same time, by Lyne and Gallay (*7, 9*). This fact is illustrated by the stress-strain diagrams and the loading and deloading cycles shown in Fig. 2. The curves correspond to papers of three different dry contents. Since the curves are



Breaking Load as a Function of Dry Content

Fig. 3

not drawn with the same load scale the stress values at these three conditions appear to be the same. But it must be realized that the breaking loads of these papers are actually very different. The elongation scale, however, is the same in each case. It is obvious from the diagrams, that the curves for 21 and 89% ovendry have a similar shape. After a high ascent at the beginning the slope decreases until a maximum is reached. Then the curve falls again to the abscissa.



Breaking Load as a Function of Dry Content on Semilog. Paper

Fig. 4

This maximum, indicating the breaking point of the sample, is not observable with those instruments which operate at constant rate of loading instead of constant rate of straining and which measure the external, steadily increasing load.

Some chemical pulps having a dry content above 40% show a different stress-strain characteristic, especially when the paper is allowed to undergo free shrinkage during drying. These curves, having a somewhat lower slope in the middle, increase almost linearly to the breaking point, as shown by curve 2. As is generally known, similar curves are obtained for a number of natural fibers, such as wool, and artificial ones, such as nylon.

In reality, there are, as everyone knows, great differences in the tensile strength and the elongation of wet webs as compared with dry papers. Webs having a dry content of 20% possess a lower breaking load per unit width ($^1/_{10}$ to $^1/_{100}$) but a higher elongation (four- to eightfold) than air dry papers. This indicates that the dependency of elongation on dry content is by no means so great as that of breaking load.

Influence of Testing Conditions

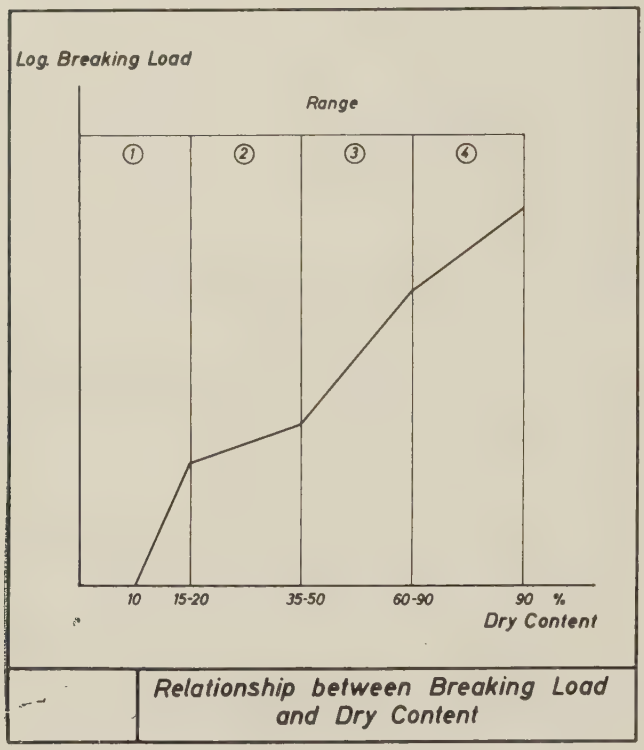
Test conditions, as far as sample dimensions or rate of straining are concerned, were found to have a relatively minor effect on the results of stress-strain measurements. For a groundwood pulp for newsprint, the breaking load per unit width and the per cent elongation at dry contents between 20 and 87% were almost independent of sample dimensions, provided that the width of the strip and its length between the clamps were at least 0.8 in. When papers of the same dry content were tested with gaps less than 0.8 in., breaking load as well as per cent elongation at break increased with decreasing sample length. Increasing the rate of straining 250 to 400 times caused only a 20% increase in breaking load. This result, well known for dry papers, is due to a logarithmic relationship between breaking load and rate of straining. The breaking elongation, on the other hand, was independent of rate of straining not only for the air-dry papers, but also for dry contents ranging from 20 to 90%. However, for dry contents less than 20% ovendry, it was found to increase as much as 40 to 50% when the rate increases as much as 400 times. This unexpected result can be traced to the observation that the wet webs, when rapidly strained, show no preference to flow at special areas as it is the case at low rates. Thereby, the whole strip is more uniformly stretched and the result is a higher breaking elongation.

Influence of Dry Content

Figure 3 shows the breaking load as a funetion of dry content for two unbeaten sulphite pulps and a groundwood. It is observed that the curves begin to rise more rapidly after dry contents higher than 40 to 50% are reached. In contrast the change of the breaking load at dry contents less than 40% is minute. That the breaking load from wet to dry papers varies a hundredfold over the range of dry contents from 15 to 90% cannot be seen clearly enough on a cartesian graph. The curves can be better differentiated, especially for papers of low dry content, when the breaking load is plotted logarithmically. That certain ranges of the

curve are linear on semilogarithmic paper, as shown in Fig. 4, indicates that the breaking load is exponentially related to dry content.

This characteristic curve, shown in Fig. 5, comprises, in general, four parts, each of which is related to a particular range of dewatering. The first and also



Relationship between Breaking Load and Dry Content

Fig. 5

the third parts show a steep rise, while the second and the fourth have a flatter slope. The second range begins at about 15 to 20% ovendry, the third at 35 to 50%, and the fourth at 60 to 90% ovendry. This type of curve was obtained for groundwood and for various species of chemical pulps. Some pulps, however, do not show the smaller rise of curve in the fourth range of dry contents, and for chemical pulps, beaten to a higher degree, the flatter, second part of the curve does not exist. For normal curves, consisting of four parts, no transition from the second to the third or from the third to the fourth range is observable, so that the curves have a very angular appearance.

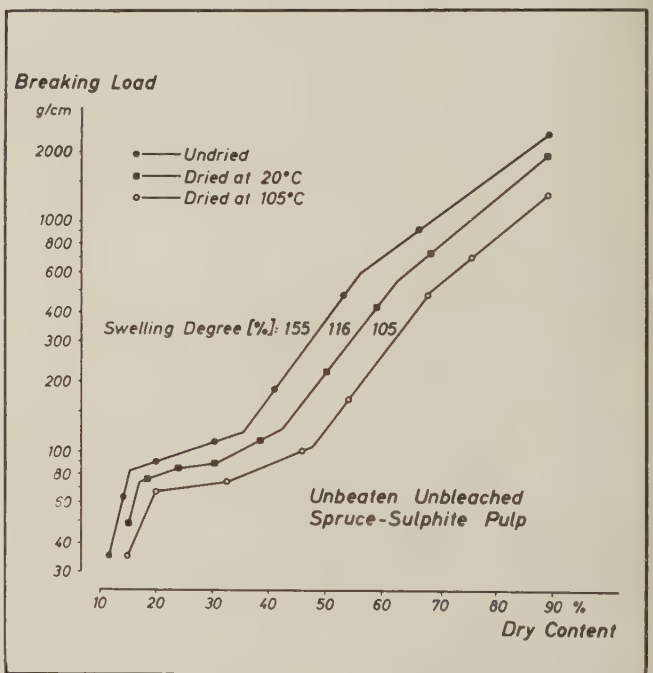
In accordance with the present theories (*7*, *9*), the fibers are held together in a paper sheet primarily by interfiber friction and by interfiber bonding. Below 20% ovendry, surface tension forces, acting in the air-water interfaces between the fibers, pulling them together, have an important effect on wet-web strength. Our experiments lead us to believe that the breaking load in the first and second ranges, that is up to 35 to 50% ovendry, is chiefly controlled by interfiber friction which is favored in the beginning by the foregoing surface tension forces. Interfiber bonds have no noticeable effect on the breaking load until the beginning of the third range and thereafter they are the controlling factor affecting paper strength up to the air-dried state.

Influence of Fiber Swelling

It is well known that fiber swelling plays an important role in determining the strength properties of chemical pulps. Figure 6 illustrates this for the development of breaking load over the entire range of dry content. Once again the breaking load is plotted logarithmically versus dry content. An unbeaten, never dried, spruce-sulphite pulp was divided into three parts, one being air-dried at 20°C., another ovendried at 105°C., and the third left undried before making into handsheets. The swelling degree was determined by the centrifugal method according to Jayme and co-workers (*25*). The never-dried pulp had a swelling degree of 155%, the air-dried 116%, and the ovendried 105%. Thereby, the breaking load for any given dry content was considerably reduced. The slope of the curve in the second range of dry content decreases somewhat with decreasing swelling degree, a tendency characteristic for all unbeaten chemical pulps. There is, however, no change of slope in the third range, but only a parallel translation of the straight line curve in the direction of increasing dry content.

Thus, there appears to be a relation between swelling degree and dry content at the beginning of the third range of the curve when interfiber bonding starts to play the major role in determining the breaking load of a paper. In fact, this dry content was attained by treating unbeaten chemical pulps of high freeness according to the centrifuge method, as shown in Table I.

From Table I it is clearly seen, that, by and large, the beginning of the third part of the curve occurs at



Effect of Swelling on the Breaking Load

Fig. 6

dry contents increasing with decreasing swelling degree. This results from the fact that at lower swelling degrees a lower percentage of the total water content is associated with the hemicelluloses and a higher percentage is free water. Interfiber bonding cannot occur so long as there is free water present.

Table I

Pulp species	Degree of swelling, %	Dry content (% ovendry) — Centrifuge method	Dry content (% ovendry) — Beginning of the 3rd range of curve
Unbleached birch, semichemical pulp	173.0	36.6	32
Unbleached spruce, sulphite A	154.8	39.3	35
Bleached straw, sulphate	138.2	42.0	39
Semibleached pine, sulphate	90.9	52.4	46
Unbleached spruce, sulphite B	91.3	53.3	47
Bleached poplar, sulphite	86.3	53.7	52
Bleached beech, sulphite	80.5	55.4	54

Effect of Beating on Breaking Load for Different Pulps

If the swelling ability of a pulp is increased by beating, the breaking load at a given dry content is also increased. This is shown in Fig. 7 for the unbleached spruce, sulphite pulp B, the swelling degree of which was diminished by drying. At dry contents above 20%, the breaking load, especially at the beginning, is greatly increased by beating. The curves

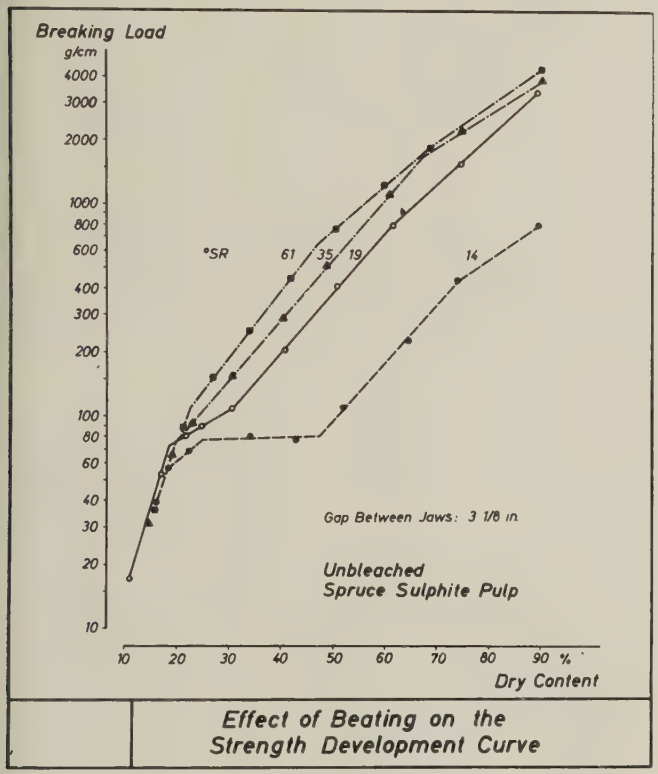


Fig. 7

in the third range were once again translated parallel, but this time toward decreasing dry contents. As a result, the flatter second part of the curves continually became smaller and smaller until it disappeared completely.

In Fig. 8 the relationship of breaking load to per cent dry content is shown for six unbeaten chemical pulps and one unbeaten semichemical pulp for papermaking, chosen at random. The semichemical pulp was produced by the NSSC process.

In each series of tests, the never-dried, unbleached, spruce, sulphite pulp A showed the highest breaking load for a given dry content. In the lower ranges of

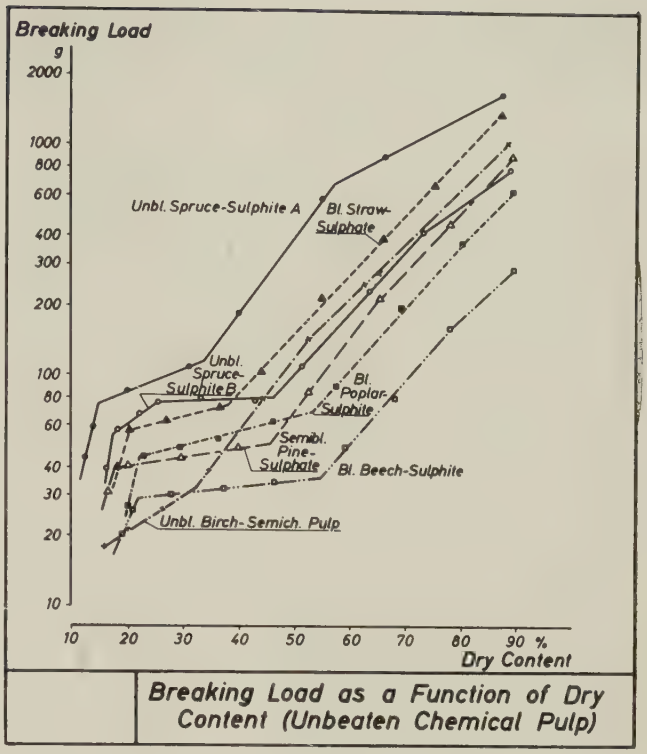


Fig. 8

dry content, up to 40% ovendry, the dried, unbleached, spruce, sulphite pulp B had the second highest strength, immediately followed by the bleached, straw, sulphate pulp. Both the bleached, hardwood pulps and the semichemical pulp, as well as the unbeaten, semibleached, pine, sulphate pulp had, within this range, the lowest values.

For dry contents above 40% the neverdried, spruce, sulphite pulp A of a high swelling ability possessed a

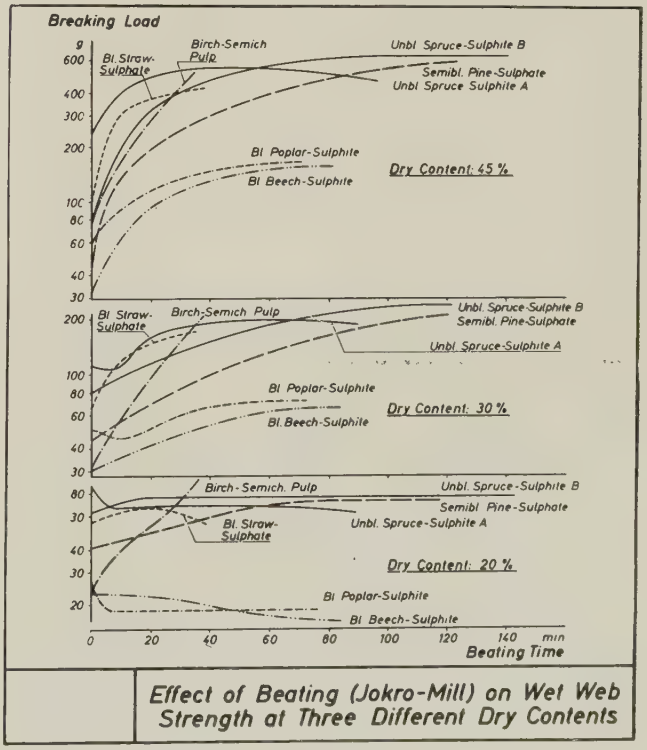


Fig. 9

breaking load three times as great as that of bleached, straw, sulphate pulp. In this area the unbleached, semichemical pulp surpassed even the spruce, sulphite pulp B and the pine, sulphate pulp.

The following curves of Fig. 9 illustrate how the wet-web strength of the seven pulps changed with beating in the Jokro-mill at constant dry contents of 20, 30, and 45%. It is seen that the wet-web strength increased with beating time. This effect is greater for the paper of higher dry content. The wet-web strength of the semichemical pulp was, after 30 min. beating, practically equal to those of the spruce, sulphite pulps subjected to the same time of beating. The bleached, straw, sulphate pulp also reached relatively high values, while the wet-web strength of the two hardwood, chemical pulps were again the lowest.

Effect of Beating on Breaking Elongation

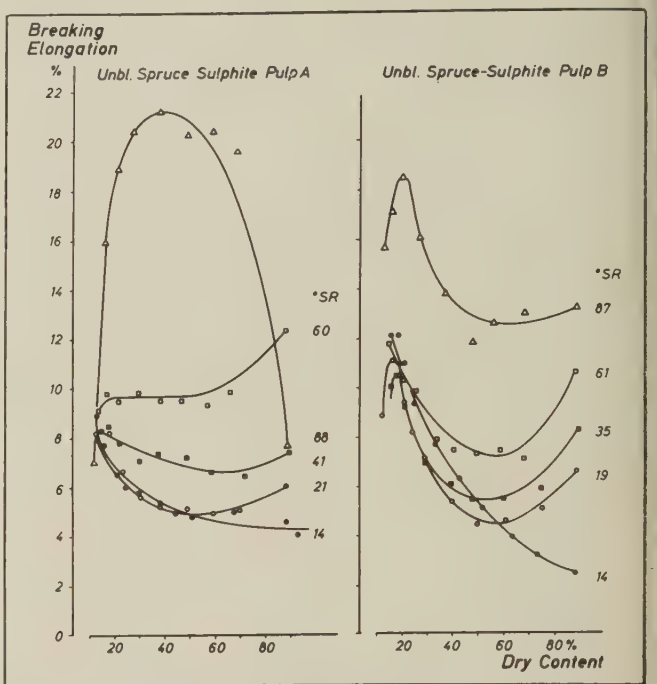
To date, very little is known about the dependency of breaking elongation of wet webs on dry content. Figure 10 illustrates this relationship for two different unbleached, spruce, sulphite pulps. Each of the curves refers to a constant beating state °S.-R. It should be recalled that the shrinkage of the samples during drying was prevented only slightly. Since the fibers of the never-dried pulp A, shown by the curves on the left, were rather weak, they were seriously shortened during beating in the Jokro-mill. The other pulp B, on the right, which was previously dried, had a lower swelling degree. In addition, it had a somewhat lower lignin content and required more time to reach a given beating state.

Apart from the highly beaten pulps, the breaking elongation decreased with increasing dry content, and, for the beaten pulps, increased again from 50 to 60% ovendry to the air-dry state. This increase of elongation at higher dry contents can be partly explained by the reversible shrinkage of the samples. The highly beaten pulp A showed a different tendency. In this case, the per cent elongation increased from the beginning of the dewatering process to a maximum of more than 20% at 40% dry content. This tendency was also a result of shrinkage, caused not by fiber shrinkage but rather by surface tension effects. Since this highly beaten pulp contained a large percentage of fines, this surface tension effect was noticeable immediately upon removal of the samples from the wire of the handsheet mold.

At dry contents higher than 50%, however, the elongation curve showed a rapid descent although shrinkage continued. A likely explanation for this is that the plasticity of bonds on the points of contact between the fibers decreases with increasing dry content and becomes at high dry contents the controlling factor. Therefore, at very high elongations, as for the highly beaten pulp A, the bonds are so strained that, although the natural tendency of shrinkage is to increase elongation, the paper cannot further be stretched and hence the elongation curve falls rapidly. For the sulphite pulp B, shown on the right, containing, at 87°S.-R. beating, only about 50% by weight fines, the shrinkage of the wet web was very much smaller, so that the breaking elongation reached its maximum at a lower value than for the highly beaten pulp A on the left.

Furthermore, from Fig. 10 it is seen that beating generally causes an increase of breaking elongation for a given dry content.

The elongation at break, up to dry contents of about 30 to 40%, that is where interfiber friction is controlling, is chiefly determined by the extent to which the fibers are curled in the web and to what extent they are stretched prior to break. This was pointed out by Rance (*26*). At higher dry contents, that is where



Breaking Elongation of Two Spruce Sulphite Pulps at Different Beating Degrees

Fig. 10

interfiber bonding plays the prime role, the stretchability of the individual bonds between the fibers, in addition to their coiling, has an important effect on the total elongation of the paper. Therefore, for a given dry content, the increase of coiling, owing to shrinkage, causes, almost without exception, an increase of breaking elongation. It was observed that there exists absolutely no relationship between average fiber length and elongation, at any dry content.

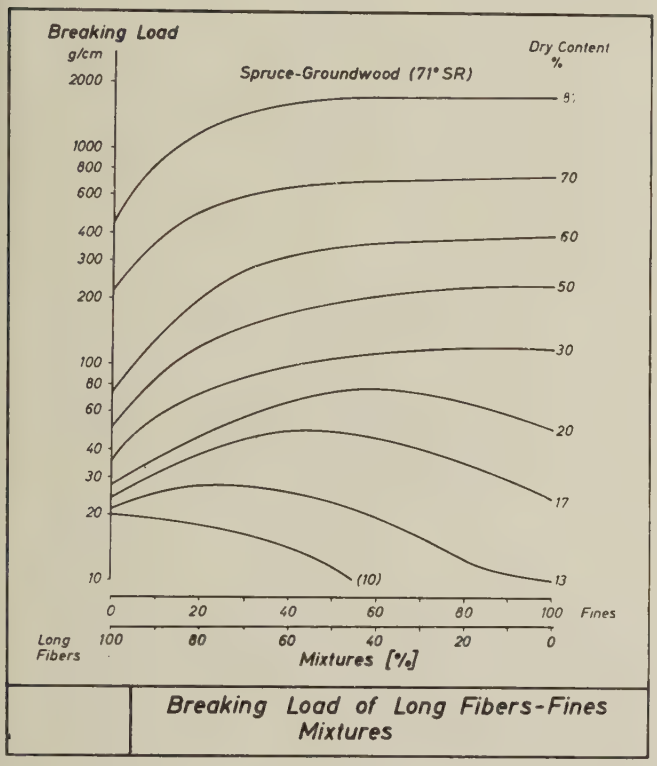
It should also be mentioned that the elastic elongation shows a similar tendency as the total elongation. It is normally 20 to 30% of total elongation.

Effect of Form Components

In the following experiments, the influence of structural elements of pulps, such as *long fibers* and *fines*, on the breaking load and the breaking elongation was investigated. In the first experiments, the long fibers (pulp retained on a screen of 40 mesh per in.) and the fines (pulp passed through a screen of 125 mesh per in.) were separated from a groundwood, containing mucilage, with a Brecht-Holl apparatus (*27*, *28*) and mixed together in definite proportions by weight. In Fig. 11, the breaking load of these mixtures is plotted versus fines content with dry content as the parameter.

As was to be expected, the breaking load of these

mixtures was dependent upon the ratio of long fibers to fines in the mixtures, as well as upon the breaking load of each component. If these were the only effects present, one would have obtained an almost linear relationship between breaking load and contents of fines. Figure 11, however, shows that at no dry content was this the case. There must be, therefore, a third effect influencing the breaking load of the mixture. We believe that this third effect is caused by the apparent density of the sheet which is greater for higher fines content. Hence, the breaking load of such pulp mixtures containing long fibers and fines is affected by (1) the breaking load of each of the components, (2) the ratio of long fibers to fines, and (3) the apparent density of each component. This is in agreement

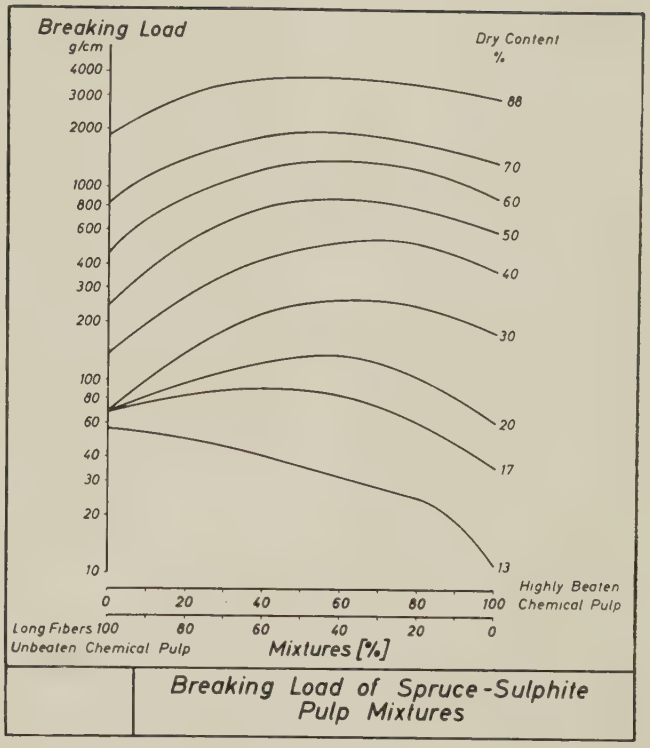


Breaking Load of Long Fibers-Fines Mixtures

Fig. 11

with our findings for all pulp mixtures at the various dry contents tested.

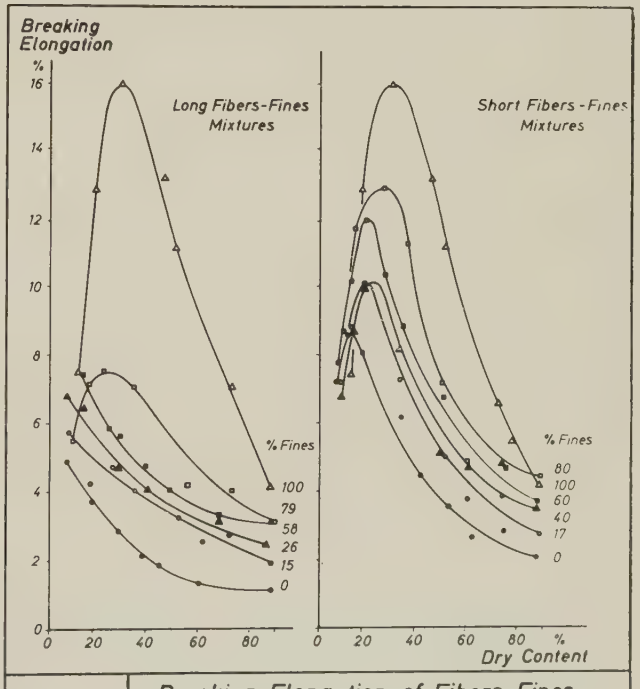
At the low dry content of 10%, the long fibers had, in accordance with their higher degree of entanglement, a much greater wet-web strength than the fines, as indicated by Fig. 11. Thus, the wet-web strength was diminished by addition of fines, although, at the same time, the apparent density of the entire mixture was enlarged. During the dewatering process, however, breaking load and apparent density of the fines increased more rapidly than was the case for the long fibers. Thereby, the differences of wet-web strength existing between these form components were reduced and a maximum of strength appeared. This maximum moved with rising dry contents toward higher fines content until, finally, at 30% ovendry, the highest breaking load was obtained for 100% fines. At 20% ovendry the dry content generally maintained on the couch role of a paper machine for manufacturing newsprint, the maximum of wet-web strength was obtained for a mixture containing 50% 'ong fibers and 50% fines.



Breaking Load of Spruce-Sulphite Pulp Mixtures

Fig. 12

In the range of interfiber bonding, that is for dry contents above 50%, the breaking load was strongly favored by the addition of fines to the long fibers until a 1:1 ratio was obtained. The breaking load of the groundwood papers containing more than 50% fines was, however, almost independent of content of fines. At 50% fines, a saturation point appears to exist similar to that asserted by Brecht and Klemm (*10, 11*) for the



Breaking Elongation of Fibers-Fines Mixtures (Groundwood)

Fig. 13

wet webs. In this condition, all long fibers were surrounded by fines so that the fines alone determined the breaking load of these groundwood papers.

Almost the same curves were obtained for mixtures of a highly beaten, chemical pulp and the long fiber fraction of the same, but unbeaten pulp, as seen in Fig. 12. Therefore, the long fibers of an unbeaten, chemical pulp have, in principle, similar properties as those of a groundwood for newsprint, in which the long fibers are relatively stiff and little or not at all fibrilated. A highly beaten pulp is similar to the fines of the above-mentioned groundwood.

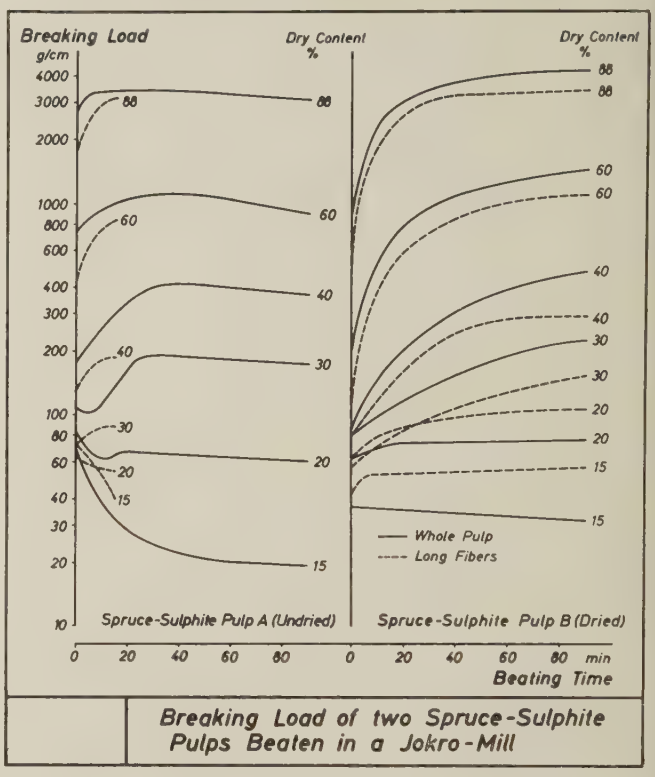
In Fig. 13, the breaking elongation of mixtures of long fibers and fines (on the left) and of short fibers and fines (on the right) of the newsprint groundwood is plotted versus dry content. The short fibers used were those which passed through a 40-mesh-per-in. screen and remained on the 125-mesh-per-in. screen of the Brecht-Holl apparatus.

As is seen from the figure, the elongation curves obtained for these fiber-fines mixtures were similar to those illustrated in Fig. 10 for chemical pulps of different beating degree. The per cent breaking elongation of the papers compared at the same dry content increased with increasing per cent fines. For a given fines content, it was found that the higher the elongation, measured for the wet web, the more rapid was the decrease of elongation with dry content. Because of the relatively low shrinkage of groundwood mixtures as compared with beaten chemical pulps, no increase of breaking elongation was noticeable between 60 and 90% ovendry.

It is further observed, as shown by Fig. 13, that at constant per cent fines and dry content, the breaking elongation of the short fibers-fines mixtures is about twice as high as for the long fibers-fines mixtures. This is especially true for the wet webs. Since the long fibers were relatively stiff and hardly fibrillated, whereas the short fibers were highly fibrillated and curled, these results again verify the fact that the breaking elongation is affected more by the degree of fiber curling than by the average fiber length.

In addition, it is worth mentioning that each short fiber-fines mixture tested showed a maximum of elongation at a dry content of 20 to 30% ovendry. The reason for these maxima is believed to be due to an irregular stretching of the wet webs, owing to a flow effect, when tested at the rather low rate of straining of 0.78 in. per min. When the rate of straining is increased, the sample undergoes more regular stretching and the breaking elongation at these low values of dry content is increased. At higher rates of straining, these elongation maxima are, therefore, not obtained. This flow effect which was only observed at dry contents up to about 20%, was especially noticeable for pulps consisting primarily of short fibers. The elongation maximum of the wet webs containing 100% fines was rather sharp, owing to the influence of a second factor—that of sheet shrinkage caused by surface tensions effects as already mentioned before for highly beaten chemical pulps.

The breaking load-beating time curves in Fig. 14 illustrate the effect of the fines on breaking load of two different types of spruce, sulphite pulps under the same condition of beating and dry content. The solid curves refer to the breaking load of the whole pulps, containing fines, while the dashed curves relate to sheets containing long fibers and no fines. Since the never-dried pulp A



Breaking Load of two Spruce-Sulphite Pulps Beaten in a Jokro-Mill

Fig. 14

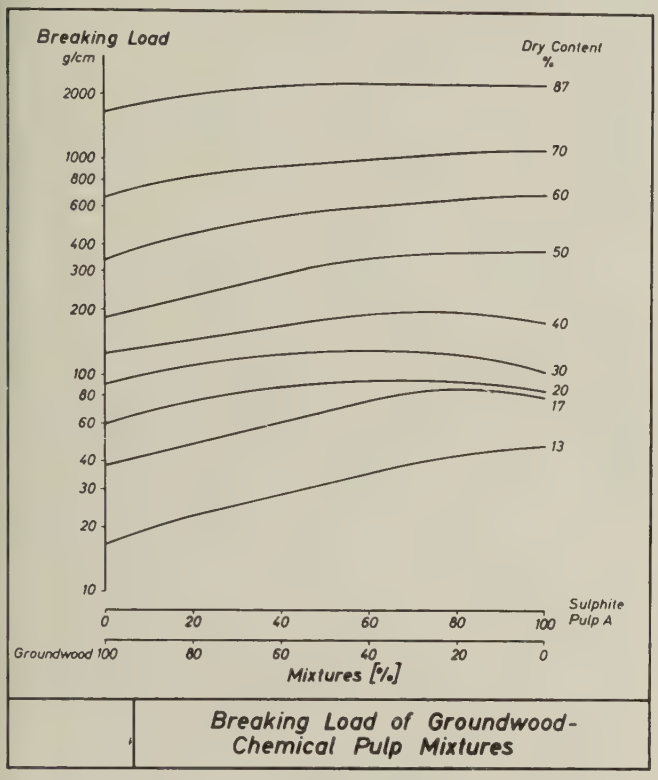
suffered an extremely high fiber shortening during beating, so that only few long fibers remained after a short beating time, the dashed curves on the left diagram are terminated after about 20 min. It can be seen that only for the wet webs of dry contents up to 15 to 20% the long fiber fraction reached a higher strength than the whole pulp, indicating that the fines have, in this range, a negative effect. At higher dry contents and constant beating time, however, the breaking load for the long fiber fraction was definitely lower than for the whole pulp, implying that the fines had a positive effect on breaking load.

In the case of another unbleached, sulphite pulp, however, we found, in confirmation of the work of A. P. Arlov (Norwegian Pulp and Paper Research Institute, Oslo) that, in the air-dry state, the long fiber fraction reached a somewhat higher breaking load than the whole pulp so that the effect of the fines was not advantageous. This indicates that for air-dry papers made from chemical pulps the nature of the pulp determines whether or not the fines are favorable for the breaking load of the paper.

At the same dry content, beating generally increased breaking load. An exception, however, was the sulphite pulp A, shown on the left; its wet-web strength at 15 and 20% ovendry was considerably diminished. This is a result of the severe fiber shortening already mentioned.

Mixtures of Groundwood and Unbeaten Chemical Pulp

The manufacturers of newsprint wish to know to what extent the wet-web strength of a pulp is dependent upon its composition, that is the proportion of groundwood to unbeaten chemical pulp. Figure 15 shows



Breaking Load of Groundwood-Chemical Pulp Mixtures

Fig. 15

the relation between breaking load and content of unbeaten, spruce, sulphite pulp in a newsprint pulp mixture at a number of dry contents. In these experiments, for each dry content the breaking load increased with addition of sulphite pulp. The primary reason for this tendency is that the chemical pulp at each dry content has a greater breaking load and apparent density than the groundwood.

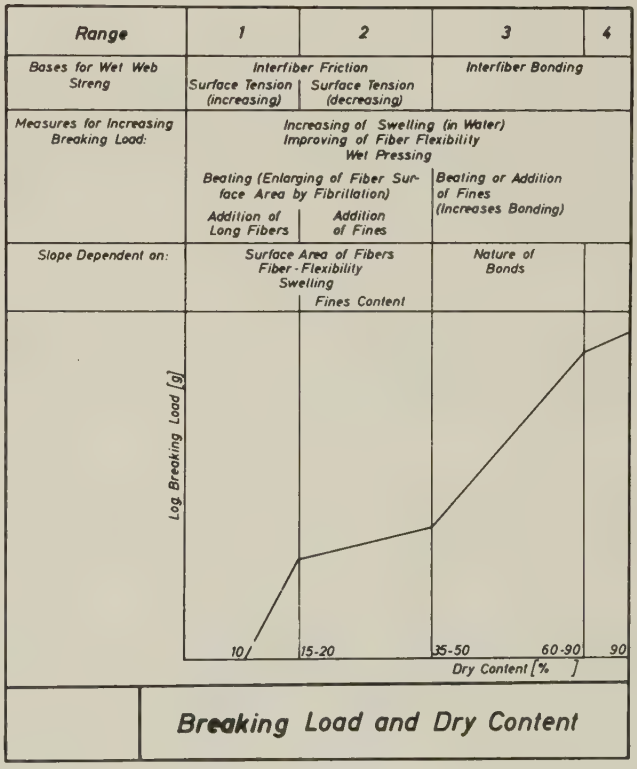
FACTORS AFFECTING WET-WEB STRENGTH

The factors influencing the breaking load of a paper from the wet web to the air-dry state and its strength development, as we now believe, are illustrated in Fig. 16 for a generalized semilogarithmic plot of breaking load versus dry content.

At very high water contents, the wet-web strength is dependent upon interfiber friction. The strength is, therefore, greater the longer and the more flexible the fibers are and the larger their surface area is. This conception is confirmed by the experiments carried out by Forgacs, Robertson, and Mason (*6*) at such astonishingly low fiber concentrations as 0.8%.

During the dewatering of the wet webs, the apparent density and the wet-web strength are increased by the action of surface tension effects. These surface tension effects occur at an air-water interface and are, at first, present only in the outer envelope of the web. With decreasing water content, air begins to enter the web, thereby increasing the air-water interfaces and, therefore, the total surface tension. Lyne and Gallay (*9*) propose that such air-filled voids begin to form at dry contents of about 10 to 12%. In other words, the original system of *fibers in water* becomes a system of *fibers and air in water*. The web contraction as well as the increase of the wet-web strength is chiefly dependent in the first range up to 15 to 20% ovendry upon the flexibility of the fibers. The higher the flexibility the higher the wet-web strength at a given dry content and the greater the slope of the characteristic curve.

The transition from the first to the second range of dewatering, that means at about 15 to 20% ovendry, occurs when the surface tension effects reach a maximum. Thereafter, as was shown by Lyne and Gallay (*9*) and by our experiments, the air-water interfaces are broken up and surface tension is, therefore, rapidly decreased. The system of *fibers and air in water* then becomes one of *fibers and water in air*. The decrease of surface tension with increasing dry content, in the range of 15 to 25% ovendry occasionally leads to a *decrease* of wet-web strength. The slope of the characteristic curve is lower in the second range as compared with the first range. This is the case because, here, the



Breaking Load and Dry Content

Fig. 16

fibers are already so closely packed that they resist a further contraction of the sheet and, thereby, the increase in wet-web strength with dewatering is slower. In the second range, increasing the fines increases the density of the web and its strength.

Up to dry contents of 35 to 50% ovendry the

wet-web strength is improved by such measures which improve interfiber friction by increasing the density of the system, that is by enlarging the number of contact points between the fibers, or such ones which enlarge the fiber surface area. A groundwood, in order to have a high wet-web strength, up to 20% ovendry, must contain a high percentage of long, flexible fibers. At higher dry contents the advantage of fines (mucilage) becomes apparent. Beating of chemical pulps increases swelling and fibrillation which favor fiber flexibility and enlarge fiber surface area, so that the wet-web strength is increased. If, however, the average fiber length is severely reduced during the beating process, as in the case of the spruce, sulphite pulp A (Fig. 14), the wet-web strength up to 20% ovendry diminishes, since in this range wet-web strength is further influenced by the average fiber length. The number of contact points between the fibers can be further increased by wet pressing.

As soon as the free water is removed from the paper the first interfiber bonds occur. Therefore, a steeper rise of the strength-dry content curve is observed, beginning at 35 to 50% ovendry. This takes place only after the free water is removed from the web and when the water of swelling from the swollen hemicelluloses, at the fiber surfaces, begins to evaporate. With higher fiber swelling, the third part of the curve begins, therefore, at lower dry contents as the result of the greater amount of swelling water present.

In the third range of dry contents the slope of the curve is independent of swelling degree and independent of the proportion of the structural elements in a chemical pulp. Thus, a greater breaking load is attained not by a steeper slope of the curve but rather by a parallel translation of the lines obtained by an increase of the number of interfiber bonds.

CONCLUSION

Surely, these investigations have not yet answered all questions. But they have presented a rather clear picture of the factors effecting the breaking load and the breaking elongation for the range—freshly formed wet webs to dry papers.

SUMMARY

A new testing device for measuring the stress-strain properties of paper in the range of dry contents from 13 to 90% ovendry has been developed. A short description of the apparatus and a study on the dependency of the testing conditions upon the results precedes the report of investigations with which the breaking load and the elongation of various pulps were measured for the whole range of dry contents.

Test conditions (sample dimensions, rate of straining) have a very small influence.

Introducing studies confirmed that the rheological behavior of wet webs is quite the same as that of dry papers.

The following investigations, carried out on some chemical pulps, a semichemical pulp, and a groundwood, showed that the breaking load is exponentially related to dry content. The breaking load at any dry content is improved by fiber swelling, as it depends on the nature of the pulp, the beating, and the drying. The breaking elongation, generally decreasing with increasing dry content, is chiefly determined by the extent of fiber curling which develops with growing shrinkage.

Special attention was paid to the role played by the form components of groundwood and chemical pulps. The law which controls the breaking load of mixtures composed of long fibers and fines, valid for wet webs as well as for dry papers, seems to be based upon three factors. They are the breaking load of each component, the ratio of long fibers to fines and the apparent density of each component. The elongation is dependent on the fiber coiling only and not on fiber length.

The results of the studies furnished a survey on the mechanism affecting the breaking load for the range—wet web to air-dry paper. Wet-web strength is determined up to about 35 or 40% ovendry by interfiber friction, that means by all conditions which bring about the number of contact points between the individual fibers. Till about 20% ovendry, the surface tension improves wet-web strength noticeably by pulling the fibers together. Above 40% ovendry the free water is removed and the water of swelling begins to evaporate. From now interfiber bonds occur and surpass the effect produced by interfiber friction more and more.

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The Physical Properties of Wet Webs

1. *Fiber-Water Association and Wet-Web Behavior*

A. A. ROBERTSON

Experimental results are presented which show graphically the changes in sheet properties (tensile strength, stretch caliper) as wet webs are progressively dried within the range of 10 to 50% solids content. The curves for a variety of pulps have a characteristic shape but are displaced relative to the per cent solids axis depending on the amount of water associated with the fibers. The data are such that a critical solids content may be determined which marks the disappearance of "free" water from the web. The "associated" water is appropriately measured by the hydrodynamic specific volume as determined by the permeability method. The properties of the associated water and the mechanisms of fiber-water association are discussed by reference to a variety of experimental methods based on drying rate, dye mobility and water retention under hydrostatic tension. Each of these methods measures a portion of the associated water, the quantity being determined by the firmness with which the water is held by the fiber and the forces of water removal which are characteristic of each method. A comparison of the methods provides a distinction between mobile and immobile water and a means of measuring them.

IN PAPERMAKING, the processes of drainage, couching, and pressing involve the application of forces to the wet web and their effect depends on the mechanical properties of the web. The behavior is determined by the physical properties of the fibers from which the web is formed and by the properties of the water. It is the purpose of the present studies to determine how fiber and water properties affect the web behavior.

A substantial basis for the work has been provided by the pioneering work by Lyne and Gallay (*14*) who have provided a coherent picture of the origin and development of wet-web strength which has received general acceptance.

The first step in the present work was to follow the changes in the wet web as it is progressively air-dried. These initial experiments gave results which were qualitatively similar to those of previous workers (*14*, *16*.) However our results and those in the literature suggested to us that a significant factor in wet-web behavior is the extent to which water is associated with the fibers as a result of fiber swelling and other phenomena. This paper, reporting on the first phase of the studies, discusses the results of experiments designed to investigate the extent and nature of fiber-water association and its effect on wet-web behavior.

Figure 1 represents a curve obtained by plotting the tensile strength of a wet web as a function of the increasing per cent solids in the web by weight as the web is air-dried. There is a rise in strength at low solids contents AB, followed by a plateau region BC which is terminated by a second rise in strength CD at somewhat higher solids-water ratios. The curve is typical of results obtained using a sample of unbeaten chemical pulp.

When the pulp is beaten the shape of the curve changes as shown in Fig. 2 which is taken from Lyne and Gallay (*14*). The plateau shortens to an inflection point which moves to lower solids contents with increased beating as indicated by the short vertical lines. Since beating is known to increase the amount of water associated with the fibers, the results suggested that the changing shape of the curve might be related to the degree of swelling. Calculations showed in fact that the hydrodynamic specific volume of the fibers as measured by the permeability method (*21*) could be related directly to the solids content corresponding to the point of inflection or the upper end of the plateau.

Thus the hydrodynamic specific volume of the unbeaten, undried sulphite pulp, whose behavior is indicated in Fig. 1, is determined to be 3.8 cc. per g.; that is, 1 g. fiber is associated with 3.18 g. water (the densities of water and fiber material are assumed to be 1.0 and 1.62 g. per cc., respectively) and the solids content of the swollen pulp is thus 24% by weight. This solids content corresponds to point C in Fig. 1. This, together with similar results, suggested that as the web is air-dried, "free" water is first removed by evaporation until at point C corresponding to a critical solids content, no free water remains and the removal of "associated" water is accompanied by a sharp rise in tensile strength. Thus a critical solids content C may be predicted from the specific volume, α and compared with the critical solids content observed in the strength

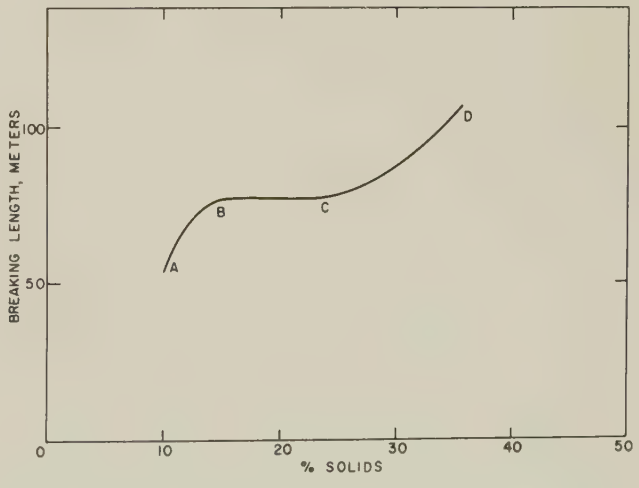

Fig. 1. Typical tensile strength development in a wet web during air-drying

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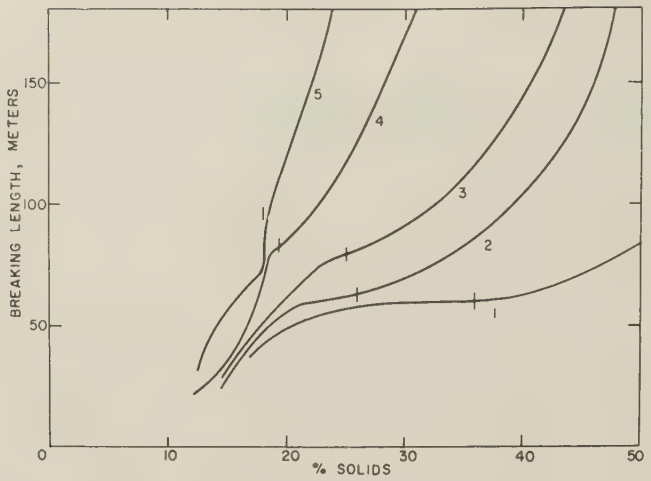

Fig. 2. Effect of beating on the development of spruce sulphite wet webs. Beating times are 0, 10, 20, 40, 60 min., respectively. From Lyne and Gallay (14). Vertical lines indicate the points of inflection referred to in the text

curve. The relation between α and C is given by the equation

$$C = 100/(\alpha + 0.38)$$

and by the curve in Fig. 3.

The hypothesis that the swelling of pulp fibers is related to the shape of the wet-web strength curve is supported by evidence in the literature. Thus the beating of a sulphite pulp (Fig. 2) (*14*) leads to the progressive displacement of the observed critical solids content from 36 to 18% which corresponds (Fig. 3) to an increase in specific volume from 2.4 to 5.1 cc. per g. This is consistent with values found by the permeability method (*20, 21*). Other data in the literature are similarly suggestive. Figure 4 is taken from the work of Nordman and Eravuo (*16*) and indicates that the critical solids content(23%) indicated by the rise in strength is substantially unaffected by the method of drying. This strengthens the belief that the effect is a property of the pulp rather than a function of the web preparation method.

The permeability method of determining the specific volume indicates that under the conditions of the measurements, pulp fibers immobilize amounts of water which are large compared to other cellulosic fibers such as rayon or cotton (*5, 21*). The nature of the fiber-water relationship is still somewhat obscure but some of the experimental work reported below provides some information on the subject.

Direct measurement of the swelling of pulp fibers by measuring moisture regain at 100% R. H. or by direct microscopic measurement is uncertain and has not been attempted here. A number of indirect methods for estimating swelling or the water retention of fibers have been developed for textile fibers and pulps. These include water retention during centrifugation (*5, 11, 13, 19, 25*) rate of drying (*1, 2, 18, 24*), the measurement of nonfreezing water (*15*), water retention under hydrostatic tension (*3, 6, 19*), cessation of dye migration (*17*), as well as measurements based on permeability (*5, 7, 20, 21*) and drainage properties (*12*). Some correlations have been obtained by applying two or more methods to fiber samples (*1, 17, 19, 22, 23*). Three of these methods have been applied

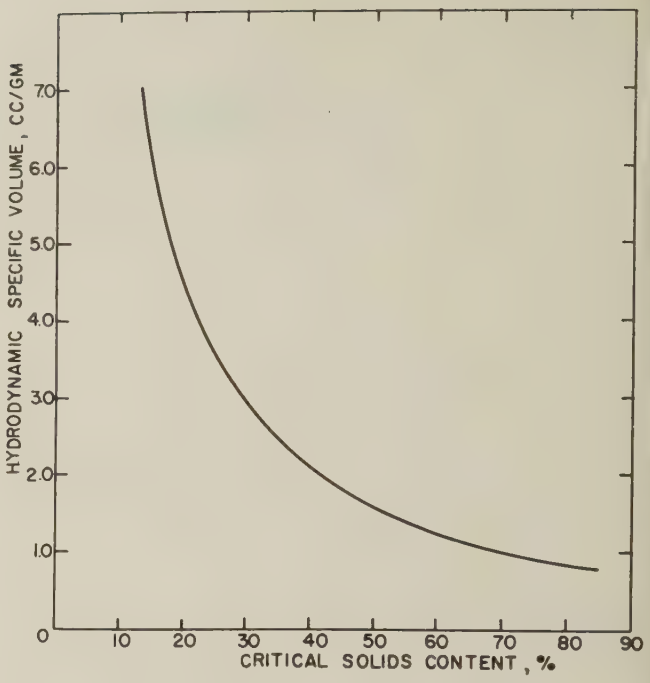

Fig. 3. Theoretical curve relating the specific volume, α, and the critical solids content C.

$$C = 100/(\alpha + 0.38)$$

The solids content is the weight of dry fibers expressed as a percentage of the total web weight

in this investigation to determine the nature of the association of the water with the fibers in a wet web in an attempt to develop a more rapid method as an alternative to the permeability technique.

EXPERIMENTAL PART

The experimental work to be described was designed to relate the properties of wet webs during drying to the extent and mechanism of water retention by the fibers. For this purpose, measurements were made of the specific surface and specific volume of the fiber samples by the permeability method and the tensile strength, stretch, and caliper of wet webs prepared from these samples. In addition, drying rate, dye mobility, and

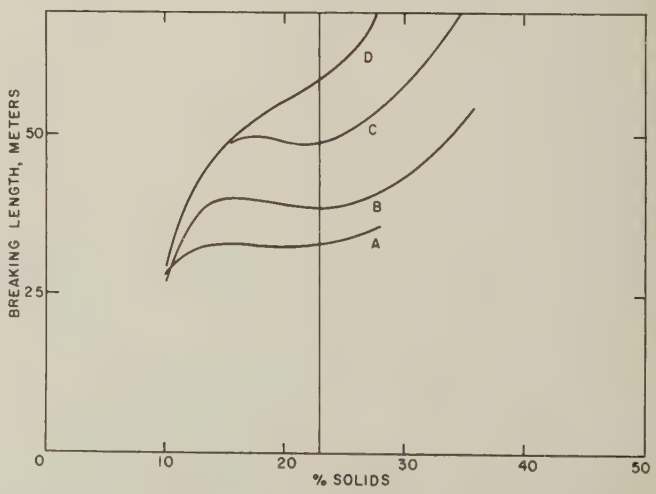

Fig. 4. Strength development with different drying methods. A, suction; B, air-drying; C, wet-pressing plus air-drying; D, wet-pressing. Unbeaten sulphate pulp. From Nordman and Eravuo (16). A critical solids content of 23% is indicated

hydrostatic tension techniques were used to obtain additional information.

The pulp samples, all softwoods, included kraft, sulphite, and groundwood, high and low yield pulps, pulps which were beaten and unbeaten, dried and undried, defibered and raw, bleached and unbleached.

The Permeability Method

The permeability measurements were made in the apparatus shown in Fig. 5. The procedure is essentially that previously described by Robertson and Mason (*21*). A pad of fibers A is formed on a permeable septum B and is compressed to a series of increasing concentrations by a sequence of increasing weights added to a permeable piston C. After each weight addition, the permeability of the pad to water is measured with the piston in place but with the weight removed. The Kozeny-Carman equation permits the calculation of the specific surface and specific volume of the fiber sample from the permeability data (*21*). A rough measure of the compressibility and spring-back of the pad is obtained at the same time.

The specific volume which is measured is the volume of the pad per gram of fiber through which water does not flow under the conditions of the experiment. This hydrodynamic volume includes the fiber with its occluded and imbibed water and in addition any water external to the fibers which is for some reason immobilized.

Wet-web Tensile Properties

The tensile properties of the wet webs were determined on an apparatus which records the force required to maintain a constant rate of elongation of a sample strip clamped at both ends. The standard conditions which have been chosen are as follows. The wet-web strips are 2.5 × 13.5 cm. and have a dry fiber content of 0.15 g. The initial distance between clamps is 9.3 cm. and the rate of elongation is 0.093 cm.

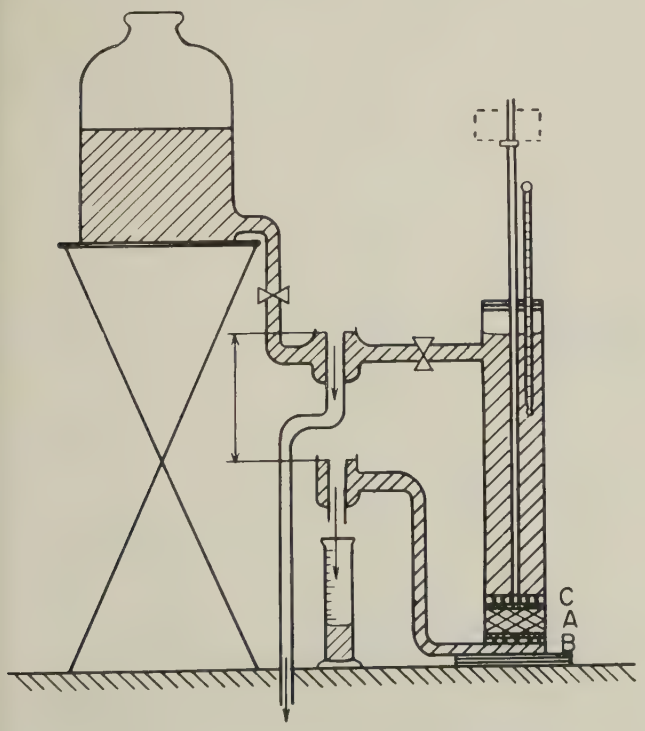

Fig. 5. The permeability apparatus

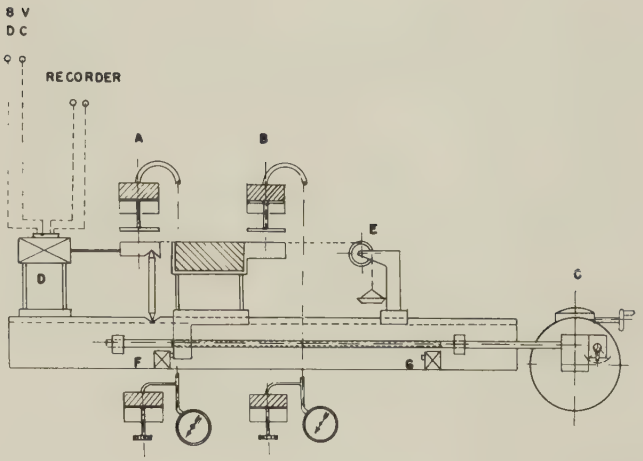

Fig. 6. The wet-web strength testing apparatus. See text for description

per sec., i.e., 1% per sec. The strips are prepared on a Williams sheet machine with a rectangular mold, on top of the wire, which is divided by cross members to produce 5 strips of the required size. The sheet machine is modified so that no suction leg is applied to the drained sheet and air is not drawn through. After formation the sheet is couched with two blotters, a sheet-metal plate, and a roll (6.8 kg., 6 cm. diameter) in a standard manner. The samples are allowed to remain on blotters until they air-dry to the solids content required. Of the five strips produced, three are used to obtain load-elongation curves, one is used for a moisture determination, and one is used for determination of caliper.

Of the strength properties only the tensile strength and stretch at failure will be considered in this paper. The stretch is reported as a percentage of the unstrained length and the tensile strength is given, after Lyne and Gallay (*14*), as a breaking length calculated on a dry weight basis as follows:

$$\text{Breaking length (meters)} = \frac{\text{tensile (g.)} \times \text{sample length (meters)}}{\text{dry sample weight (g.)}}$$

The mechanical features of the wet web tester are depicted in Fig. 6. The sample strip is held by pneumatically operated clamps A and B with a standard pressure of 12 p.s.i. and a small square of blotting paper is inserted with the strip in each clamp to avoid squeezing water into the test section and producing breaks at the clamps. The strip is supported on the surface of a trough of mercury which is integral with the moving clamp B. The clamp and trough are mounted on a mobile carriage which is moved by a constant-speed motor C along a bed by the use of a rotating screw arrangement. During the elongation the force transmitted through the sample to the stationary clamp is measured by a strain gage D (Statham G1-16-250) and is recorded on a chart recorder (Brown, 0–3 mv.). Provision has been made for coarse and fine zero adjustment, and the control of gage and recorder sensitivity. By suitable calibration the record indicates load as a function of elongation. The gage may be calibrated by connecting weights over the pulley E to the stationary clamp A. The drive is provided with a clutch arrangement which is actuated by adjustable limit switches F and G in such a way that the carriage may be automatically stopped at a fixed initial posi-

tion for inserting the sample; or the elongation may be stopped at a fixed point to observe stress decay or the sample may be continuously subjected to cycles of strain.

Caliper

Two methods have been used for determining the caliper of the wet webs: (a) the use of a micrometer gage so arranged that the first contact with the web is sensed electrically and (b) direct observation of the webs in cross section. The second was found to be the more reliable and the results to be reported were obtained in this way. The wet-web strip was cut transversely into quarters with scissors and two or more 4-mm. coupons were cut transversely from each quarter, mounted on edge on the stage of a microscope, and the caliper measured with a calibrated ocular. The mean of the 8 to 10 measurements was recorded as the caliper of a given sample. Measurement by direct observation reduces error due to fibers protruding from the body of the web and avoids the compression implicit in most mechanical caliper gages.

Rate of Drying

A sample prepared as for wet-web testing was suspended from the arm of an analytical balance by a wire into a convection oven operating at a nominal temperature of 105°C. The rate of drying was determined by observing the time intervals taken for successive 100 mg. losses in weight. In most cases a constant drying rate was established after a short initial period and this continued until a critical moisture content was reached after which the drying rate progressively decreased. The critical moisture content was estimated from a graph of drying rate versus solids content.

Similar techniques have been used in studying textile materials (*1*, *2*, *8*, *18*, *24*) and the interpretation usually given (*8*) identifies the constant-rate period with the removal of mechanically held water and the critical moisture content with the "saturation regain." Our present view is that during the constant-rate period evaporation occurs at the web surface to which the water migrates. When the freely mobile water is removed the slower migration reduces the drying rate. As the moisture content is reduced toward the point that migration no longer occurs, the zone of evaporation expands into the sample. Both the critical moisture content and the cessation of migration should be detectable in the drying rate curve under suitable conditions.

Dye Mobility

The object of this technique is to compare the amounts of immobile water in wet webs prepared from different pulp samples. The procedure is similar to that described by Preston and Bennett (*17*) for textile fabrics. Wet-web strips are prepared in the normal way from fibers suspended in a dilute solution of a non-substantive dye (Kiton Fast Red G, Ciba). Each strip is air-dried to a different solids content which is measured by cutting off part of the strip and weighing it wet and dry. The sample is laid flat on a glass plate and a microscope cover glass is placed across the middle of the strip. Drying is continued. At lower solids contents, water will move from the center of the strip as the ends dry thus partially stripping the dye under the glass and intensifying the color beyond the edge of the slide. At higher solids contents the water is immobile and drying under the glass must be by evaporation rather than migration and the color remains uniform along the sample. The solids content corresponding to cessation of migration can be determined within 2%.

The interpretation of this behavior in relation to textile fibers (*17*) is that in the wet-web or fabric capillary water forms a continuous film throughout the fiber assembly, surrounding each fiber and fiber-fiber contact point. Liquid migration takes place readily until this capillary water has been removed. The remaining water is now nearly all within the fiber. Preston and Bennett report good agreement between this method, the centrifuge method and the drying-rate method.

The Hydrostatic Tension Method

The apparatus schematically shown in Fig. 7 is essentially that of Preston and Nimkar (*19*) and is similar in principle to that used by Barkas (*3*, *6*). Pads are formed in the permeability apparatus, compressed by the piston with a pressure of 110 g. per sq. cm. and are transferred to the sintered glass plate A which is suffused with water from below. A hydrostatic tension of approximately 15 cm. of mercury is applied by lowering the capillary outlet B. The pads were typically 5 to 8 g. and equilibrium was established after 6 hr. The water retention is measured by weighing the pad wet and dry and the air intrusion (per cent voids) can be calculated from the measured pad volume. It was found during the investigation that smaller fractional gram pads (0.1 to 0.2 g.) could be used without loss of reproducibility but with considerable saving of time. The smaller pads are used for routine measurements while the larger pads are used to investigate air intrusion, shrinkage, moisture distribution in the pad, and the kinetics of water removal.

The free water in the pad is considered to be con-

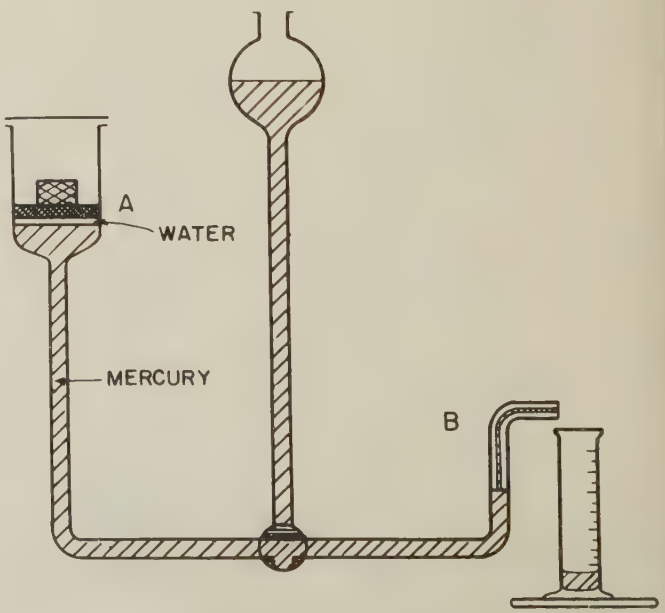

Fig. 7. Apparatus for hydrostatic tension measurements

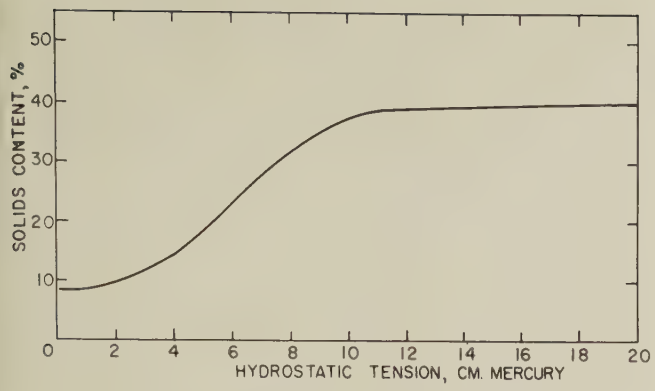

Fig. 8. Water retention by a pulp pad as a function of applied hydrostatic tension

tinuous with the water in and below the plate and so is subject to the same hydrostatic tension. Previous workers have explained the equilibrium behavior as a balance between the hydrostatic tension and the surface tension acting in the interfiber capillaries in the pad. The effect in our experiments, of varying the surface tension, or the pad volume by compression, however, do not produce changes in the water retention of the magnitude suggested by this picture and we are led to suppose that additional retention mechanisms are involved.

The effect of imposing and increasing the hydrostatic tension is to draw water from the pad with pad shrinkage and air intrusion. Water retention decreases with increasing tension (Fig. 8) until at tensions above 10 cm. mercury the change becomes rather small. The standard tension of 15 cm. was chosen for the purpose of comparing pulps. Above this suction there was a risk of sucking air through the glass plate.

RESULTS

Wet-Web Tensile Strength

The relation of the hydrodynamic specific volume to the inflection point in the tensile strength development curve has been demonstrated by experiment.

Figure 9 shows the results obtained with a bleached sulphite pulp prepared by disintegrating a dry pulp sheet. The permeability specific volume was determined to be 2.45 cc. per g. corresponding (Fig. 3) to a critical solids content of 34.5%. Curve A represents the data obtained by air-drying according to the method outlined above while curve B corresponds to variation in solids content by wet pressing. Curve C represents wet-web strength development by air-drying in the presence a soap which lowered the surface tension to approximately 35 dynes per cm. The inflection point in each curve occurs close to the predicted value.

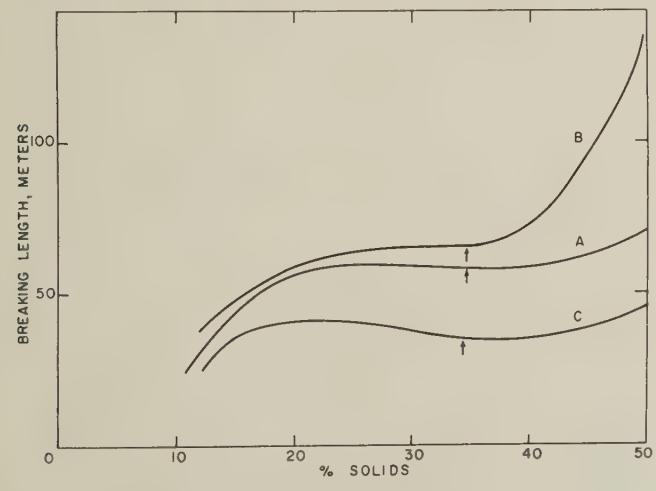

Fig. 9. Strength development with different drying methods: A, air-drying; B, wet-pressing; C, air-drying with reduced surface tension. Unbeaten bleached sulphite. Arrows indicate predicted critical solids content from the permeability data

A variety of pulps were investigated by the normal method of air-drying. A description of the samples and the results of permeability determinations are included in Table I. The solids contents corresponding to the observed inflection points in the strength curves are listed in Table II together with the critical solids contents calculated from the permeability results (Fig. 3). A correlation coefficient of 0.96 for the series verifies the suggested relationship. Typical tensile strength-solids content curves for five of the samples are shown in Fig. 10.

The data have also indicated some correlation between the *level* of the tensile strength and the hydrodynamic specific volume of the fibers. This relation, however, involves other factors and will not be developed in this paper.

Wet-Web Caliper

The caliper data were normalized by calculating the specific volume of the webs (volume in cc. of the web per g. of dry fiber). These values were plotted as a function of increasing solids content during drying. The curve shapes vary from pulp to pulp and presumably reflect differences in compressibility, elastic recovery, interfiber frictional properties and perhaps bonding. Sample experimental curves are shown in Fig. 11. The graphs for wood pulps show a fluctuation in caliper in the neighborhood of the critical solids content predicted by permeability measurements. The lower curve represents the calculated specific volume of a web if no air intrusion occurred. At any solids content the difference between the ordinates of

Table I. Description of Pulp Samples

Sample no.	*Description*	*Permeability Data* *Specific volume, cc./g.*	*Specific surface, sq. m./g.*
1	Commercial newsprint groundwood	2.98	4.80
2	Commercial spruce sulphite, dried	2.52	1.10
3	Spruce, sulphite, high yield (63%)	4.57	1.06
4	Spruce, kraft, 49% yield	4.14	1.09
5	Sample 2, beaten, 380 Canad. freeness	3.43	1.96
6	Spruce, sulphite, 51% yield	4.35	1.08
7	Sample 6, beaten, 430 Canad. freeness	5.31	2.20
8	Spruce, kraft, high yield (59%), raw	2.94	0.62
9	Commercial kraft dried	3.18	1.23
12	Spruce, sulphite, high yield (68%)	4.00	0.90
15	Sample 9, beaten, 400 Canad. freeness	4.03	2.60
16	Spruce, kraft, 53% yield	3.72	1.16
17	Spruce, sulphite, 59% yield	4.33	1.29
18	Dacron, 0.1 denier per filament, chopped, 1/16 in.	(0.72)[a]	(0.90)[a]

[a] Estimated.

Table II. Critical Solids Content, %, Indicated by Different Experimental Methods

Sample number	Permeability	Strength increase	Caliper minimum	Stretch curve	Drying rate	Barkas method	Dye migration
1	29.8	30	28	30	40.2	..	48
2	34.5	38	36	39	42.3	47	52
3	20.2	20.5	20	21	27.2	25.8	40
4	22.2	20.5	20.5	21	27	25.7	40
5	26.3	26	26	28	37.5	37	51
6	21.2	22	23.5	21	27.5	24.4	47
7	17.6	20	18	18	28.9	23.3	45
8	30.2	28	28	30	31.5	29.6	32
9	28.1	28	..	29	43.1	40	55
12	22.8	23	25	24	30	26	35
15	22.7	..	..	..	33.1	32.2	53
16	24.4	..	..	..	28.4	27	40
17	21.2	..	..	..	27.8	24	43

this curve and an experimental curve measures the volume of air per unit weight of fiber in the pad. The solids contents corresponding to the caliper minima are listed in Table II. The correlation coefficient between these values and the critical solids content predicted from permeability measurements is 0.95.

Wet-Web Stretch

The elongation at failure is immediately derived from the load-elongation curves (Fig. 12). The measurement is made along the elongation axis from the inception of stress to the break point. This property varies greatly from pulp to pulp among the samples tested and undergoes considerable change during the course of drying. Typical stretch curves are shown in Fig. 13. There is some scatter in the data but the curve shape appears to be simple and similar for a variety of pulps. The curves are shifted relative to the solid content axis in conformity with the variation of the critical solids content. Although often no sharp discontinuity or inflection is observed, the decrease in stretch with drying, which is rapid in the range of low solids contents, is slowed down markedly in the neighborhood of the critical solids point. Estimated inflection points are listed in Table II.

The stretch values obtained are low compared with the data of Lyne and Gallay (*14*), Nordman and Eravuo (*16*), and other workers. The reason for this is uncertain but may be related to the rate of loading or to the

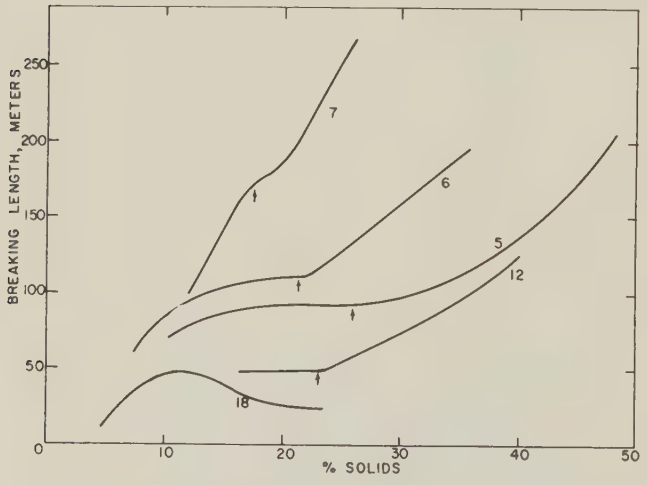

Fig. 10. Strength development for several pulp samples (Table I) and Dacron (No. 18 .) Arrows indicate predicted critical solids content from permeability data

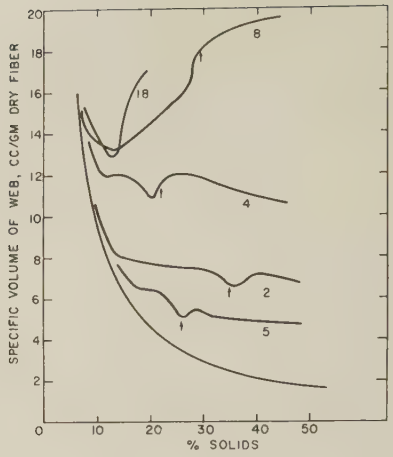

Fig. 11. Caliper as a function of solids content during drying for several pulp samples (Table I). The caliper measurements have been normalized by calculating the specific volume of the web. Arrows indicate the predicted critical solids content from permeability data. The lower curve represents the theoretical specific volume of a web if no air intrusion occurred

sample dimensions. A small portion of the discrepancy may result from the introduction of blotters which raises the solids content very near the clamps but it is thought that this does not disturb the picture of the general behavior.

Wet-Web Drying Rates

Drying-rate curves were obtained for a number of pulps according to the procedure outlined above. The end of the constant drying rate is believed to result from a decrease in the ability of water to migrate to the surface of the sample because of a fiber-water association. A typical example of the experimental curves is shown in Fig. 14. Solids contents corresponding to the end of constant-rate drying are listed in Table II.

The range of solids contents over which drying is constant has been shown to be unaffected by the variation of experimental conditions over a considerable range of temperatures, sheet weights, and areas.

Dye Mobility

The upper limit of solids contents for which dye mobility is observed in wet-web samples is recorded in Table II. The results are somewhat dependent on subjective judgment but an estimation can be made with an accuracy of ±2% and a reproducibility of about the same order. The results for pulp fibers do not appear to be affected by varying the bulk of the web or by applying pressure to the cover glass during the evaporation.

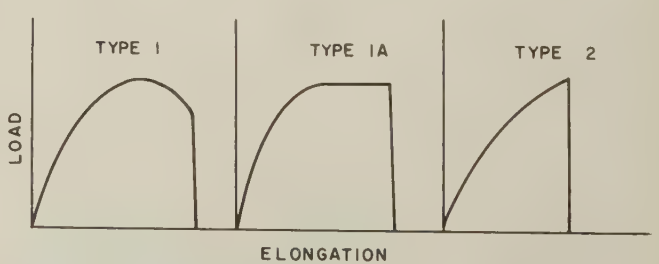

Fig. 12 Typical load-elongation curves obtained on the wet-web tester

Moisture Retention Under Hydrostatic Tension

Moisture retention values were determined by the Barkas method (*3*) at tensions of about 15 cm. of mercury and the result for each pulp was found to be relatively constant (±1%) for changes in tension (±3 cm.) about this value (Fig. 8). The equilibrium solids contents for a variety of samples are included in Table II.

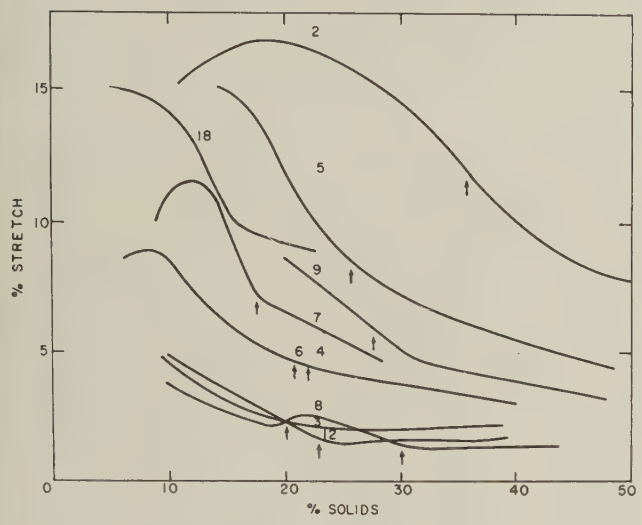

Fig. 13. Stretch as a function of solid content for several pulp samples (Table I). Arrows indicate predicted critical solids content from permeability data

The pads were normally compressed (110 g. per sq. cm.) during formation so that they might be conveniently transferred to the sintered plate. This procedure resulted in pads with densities similar to those of the corresponding wet webs. When the effect of higher and lower pressures was studied, it was found that the moisture retention showed less than 2% change although the final pad volumes were varied by 50%.

The uniformity of moisture distribution in the pad was measured in several instances by determining the solids content of portions of the pad independently. The results showed that at equilibrium the moisture content was constant within 1% through the pad.

DISCUSSION

General

The work described above represents one of a series of studies of the effect of physical fiber properties (swelling, flexibility, fiber length, surface area, and character of the fiber surface) on the properties of wet webs and pads. It has been demonstrated using various techniques that the nature and extent of the association of fiber and water varies from pulp to pulp and that these differences are reflected in the wet-web behavior during drying.

The most striking correlations appear when the permeability specific volume of the fibers is related to the tensile strength development, the stretch behavior and the caliper during drying as summarized in Fig. 15 and Table II. The specific volumes varied from 2.5 to 5.3 cc. per g. corresponding (Fig. 3) to critical solids contents of 35 to 17.5%. The individual correlation coefficients between the permeability specific volume and the critical solids contents indicated by the wet-web properties are 0.98, 0.96, and 0.95 for stretch, strength, and caliper, respectively. This and other supporting evidence has led us to the conclusion that the permeability specific volume as measured has a quantitative physical significance. The point at which

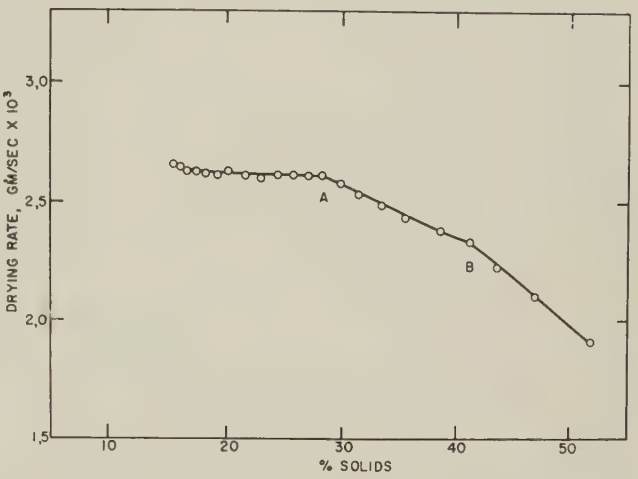

Fig. 14. Drying rate curve for sample 3 showing the end of constant-rate drying at A and a possible second transition point at B

free water has been removed from the pad and the removal of associated water begins clearly corresponds to an inflection in the strength curve, a minimum in caliper and an inflection in the stretch curve.

Wet-Web Behavior During Drying

The following picture of the development of wet-web properties has emerged during the course of this work.

In our experiments the web, as it is formed and couched, contains little air. In the initial stages of drying there is a rapid decrease in caliper with little air intrusion as water is removed (Fig. 11). The stretch is high (Fig. 13) and the strength which here is due to interfiber friction may increase (Fig. 10) due to increasing interfiber contacts. The consolidation can be considered to result from surface tension forces and the extent to which consolidation proceeds depends upon the initial couching conditions, the surface tension, the specific surface of the fibers and the compressibility of the fiber network. Thus although beating does not change the compressibility of a pulp greatly as indicated by observations made during the permeability measurements, the caliper of the wet webs from the beaten pulp is less due to the greater surface. Conversely two pulps with the same specific surfaces will form wet webs whose caliper is inversely proportional to their compressibility. It may be demonstrated similarly that a reduction in surface tension results here in a bulkier web with rather less strength and stretch though these effects are greater in subsequent drying stages.

A second stage of drying is considered to begin when

air intrusion becomes marked. Under the conditions of our experiments this generally occurs at about 12% solids for unbeaten pulps (Fig. 11) and somewhat higher for groundwood and beaten pulps presumably because of their greater specific surface. During the second stage, interfiber capillary water is replaced by air leaving an envelope of water around each fiber and around each contact point.

The consolidating surface tension forces are opposed by forces of elastic recovery tending to expand the pad. When the geometry of the system becomes such that a maximum surface tension effect is produced, a minimum caliper is reached and further water removal results in an expansion of the web. Such behavior is noted in webs formed of glass (*14*) and Dacron fibers (sample 18, Fig. 11) of uniform length and diameter which show caliper minima at 24 and 13% solids by weight, respectively. It may be significant that these minima both correspond roughly to a volume ratio of fiber/water/air of 1/9/7 and both correspond to a maximum wet web strength (Fig. 10).

The behavior of pulp webs is more complex than that of Dacron and glass because of the heterogeneity of the fibers, the interaction with water and the greater plastic deformability of the fiber and the fiber network. Thus the experimental curves suggest that the phenomenon which produces the minimum exhibited in the webs of rigid synthetic fibers is modified in the case of wood pulps and a variety of behavior is shown which is explained in terms of fiber properties and associated water. Thus sample 8 which shows a high recoverable elasticity and little subsequent bonding behaves much like dacron while some other pulps decrease in caliper throughout this second stage.

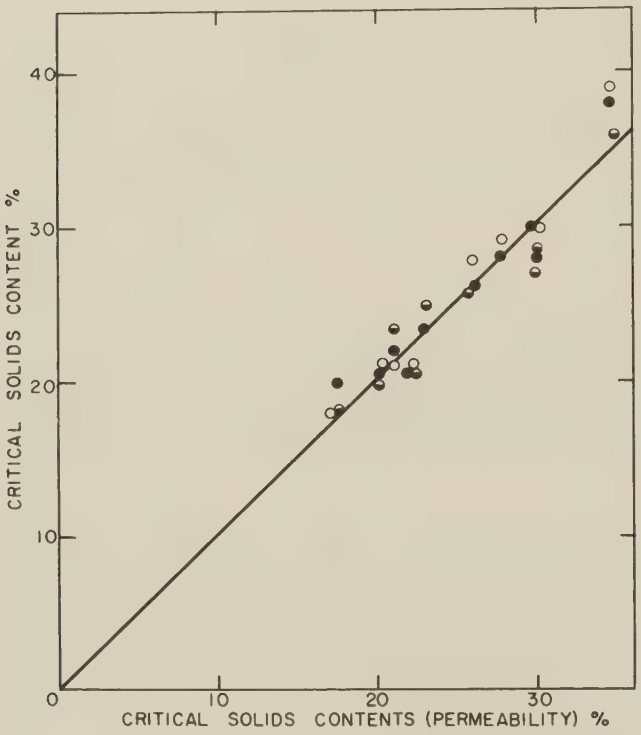

Fig. 15. Critical solids contents based on wet-web data plotted as a function of the critical solids content predicted from permeability data

Closed circles, strength inflection; open circles, stretch inflection; half circles, caliper minimum.

Although interfiber forces are presumably increasing, the ability of the stressed webs to maintain sliding contacts or to reform broken contacts decreases as water is removed. This is shown by the rapid decreases in stretch in this region (Fig. 13) and the observed losses or relatively modest gains in strength (Fig. 10). In reference to this point the shape of the load elongation curve tends to change from type 1 to type 2 (Fig. 12) as the critical solids content is approached.

The second stage of drying ends with the approach to the critical solids content. In most cases the experimental caliper curves tend to show an increase of compacting forces just before the critical solids content is reached (Fig. 11) and this is followed by a relaxation. It is tentatively suggested that bonding becomes important here and the degree of expansion depends partly upon the extent to which the surface tension forces are replaced by more permanent and rigid bonds. However, our work so far has not permitted us to be more specific about the nature of the bonding at these solids contents. The continued ability of water to migrate from fiber to fiber (dye mobility experiments) suggests that water is still present at the fiber-fiber contact points and may represent a major component of fiber adhesion through the continued operation of surface-tension forces, presumably involving greater forces operating on local fiber elements drawn into close proximity. This latter suggestion is in line with the thoughts expressed by Campbell (*4*).

Drying beyond the critical solids content is characterized by a more or less rapid increase in strength (Fig. 10) a caliper shrinkage of the more rigidly bonded webs (Fig. 11) and relatively moderate or negligible decreases in stretch (Fig. 13). This continues up to and beyond 50% solids which we have arbitrarily taken as the upper limit defining wet webs.

The lateral shrinkage up to this point is minor. For example the unrestrained area shrinkage of a web formed from commercial sulphite was found to be less than 0.5% between solids contents of 10 and 50%.

The Associated Water

The measurement of the hydrodynamic specific volume by the permeability method as an indication of fiber swelling has been the subject of some controversy (*9*) primarily because of the surprisingly high numerical values. As applied to textile fibers the same method appears to give results which are consistent with measurements made by such alternative methods (*5*, *22*) as retention under hydrostatic tension or centrifugation, dye mobility, drying rate, etc. However these alternative methods have failed to give the same corroboration for pulp fibers. Thus the objective of developing a method for determining associated water which would be equivalent to the permeability method but more rapid and convenient, has not yet been achieved.

We have taken the position that the permeability method measures the total water associated with the

fibers. This total includes not only (a) water held within the fiber by association with the cellulose and hemicellulose as water of swelling and water occluded in the lumen or other free volume but also (b) water held externally to the main fiber structure by fibrillae or in re-entrants in the fiber surface or association with sorbed hemicellulose. The amount of water held in this extra-fiber water layer appears to distinguish wood pulp fibers from other fibrous materials both natural and synthetic. It is suggested that the external associated water has greater or less mobility depending on the pulp sample, and that the various techniques for measuring water retention give different results depending on the nature and magnitude of the forces applied to this film.

The forces applied to the associated water in the permeability technique are small, the pressure drop across the pad being held normally at 1 to 3 cm. water per cm. of pad length. This pressure may be reduced or increased by a factor of three without changing the results. However when high pressure drops are imposed the permeability has been shown by Carroll (*5*) to increase with some pulps. This could be attributed to a reduction in associated water as a result of appreciable shear forces.

Experience with the permeability method has shown further that a reduction in the associated water can be caused by mechanical pressure. In general if a pulp pad is compressed to the point that the void fraction (free water) is less than 0.5 (that is, if the fibers and associated water account for more than half the pad volume), the permeability data at these higher compressions indicate decreasing specific volumes (*5*).

In methods for measuring associated water by centrifuging, hydrostatic tension or drying rates, the forces acting on the film are normally much higher than in the permeability method and the indicated associated water will be less than the permeability value by an amount dependent on the magnitude of the force and the mobility of the water. Calculations have shown (*5*) that the results from the centrifuge method are also likely to be low due to deswelling under compression.

It should also be pointed out that, except for the permeability method, the techniques we have used to estimate associated water depend upon the migration of water from fiber to fiber through the web. The possibility exists that the results are influenced by the web structure—for example, the number of interfiber contacts. However, in instances in which this was checked for pulps—by varying the pad compression in the hydrostatic tension experiment and by varying the couching pressure in preparing samples for the drying-rate or dye-migration experiments—the difference in pad density did not affect the results.

These experiments have led us to believe that the immobile water and the total associated water which we are discussing are functions of the chemical and physical state of the wood pulp fibers and within rather wide limits their magnitude or measurement is not affected by the pad or web structure. Exceptions may exist in the case of chopped textile filaments which produce expanded, nonbonded webs on drying. Here the lack of fiber contacts hinders or prevents migration and leads to spuriously high values for associated water measured by dye-migration, rate-of-drying or hydrostatic-tension methods. The low solids contents, observed when tests are carried out under the standard conditions for dye migration or hydrostatic tension, are raised when the test is carried out under pressure. Under similar conditions the results with wood pulps are unaffected.

The results for experiments carried out with a number of pulps are presented in Fig. 16 and Table II. In each case, the dye mobility technique indicates that the immobile water is less than the associated water as measured by permeability and that there is little correlation between the two. The other two methods fall somewhere between and the results show some correlation both with the other methods and with each other. Some recent work has suggested that a second transition in the drying rate curves (Fig. 14) may be identified with the disappearance of mobile water and so may be correlated with the results obtained by dye migration.

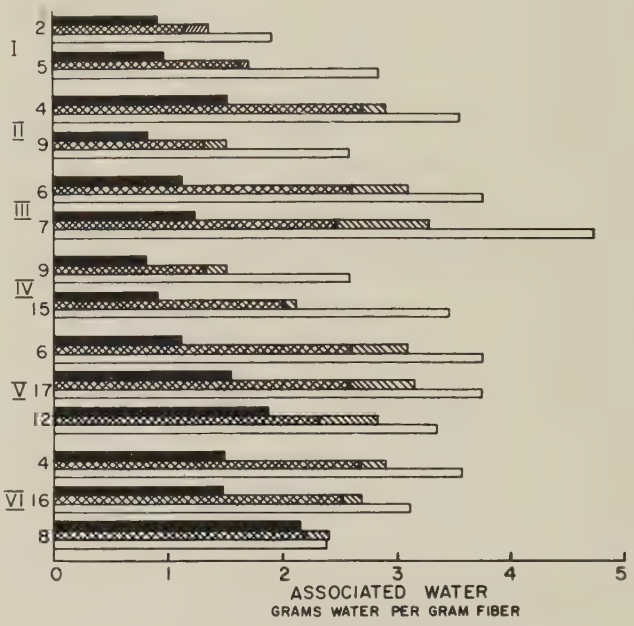

Fig. 16. Histograms showing the amount of water associated with fibers as determined by various means

Solid bar: dye migration. Cross-hatched bar: hydrostatic tension and drying rate. Open bar: permeability. I, unbeaten and beaten dried sulphite. II, Virgin and dried kraft. III, Unbeaten and beaten virgin sulphite. IV, Unbeaten and beaten dried kraft. V, Sulphite pulps of increasing yield. VI, Kraft pulps of increasing yield.

The hydrostatic tension and rate of drying techniques tend to give similar results for many of the samples. The differences are attributed to the nature of the forces applied to the water in the two cases and to the consideration that the hydrostatic tension method is based on a static equilibrium and the other is a dynamic test. The results derived from the two experimental methods do not appear to have the significance of the permeability results in the present context since they measure only a part of the associated water and their relation to the wet-web strength, stretch and caliper is not apparent. It is, however, noteworthy that the methods provide data which are reproducible under varying test conditions and may be shown to vary systemati-

cally when a given pulp is beaten to varying degrees or when a given wood is pulped to various yields or when a pulp is dried. The data are therefore thought to reflect a property of the pulp the measurement of which has potential value in further studies of the relation of fiber and water. The assessment of the mobility of the associated water which they provide may well have significance in the technical processes of wet pressing and drying in which migration of water from fiber to fiber is important.

A clear differentiation may be seen between virgin pulps (samples 4 and 6, Fig. 16) and pulps which have been dried (samples 2 and 9). Both the total water associated with the fibers and the immobile water are less in the latter case. In addition, much of the associated water is rather loosely held as judged by the proportion which may be withdrawn from the pad by hydrostatic tension.

High-yield pulps (samples 8 and 12) appear to be distinguished by the relatively large amount of immobile water which they contain. This probably reflects a lesser degree of fiber collapse in preparation and handling rather than a greater internal swelling of the wall material.

It follows from the above that at a given solids content a wet web which has been formed from a pulp which has been dried has more free and mobile water than a web of high-yield fibers. Normal pulps (samples 4 and 6) fall somewhere between. It was also noted that stretch and density values followed the same order. Since experiments with wet pressing have shown that an increase in density is accompanied by a decrease in stretch, it may be concluded that the stretch is related to the amount of mobile water in the web. This conforms to the idea that the amount of mobile water determines the extent to which stresses in a strained web may be reduced or redistributed without rupture of the web. Interfiber contacts which are maintained by surface tension forces are able to accommodate large distortions. Greater amounts of mobile water permit larger distortions and facilitate the formation of new bonds as the web is strained.

It is interesting to note that beating samples 2, 6, and 9 to produce samples 5, 7, and 15 has failed to increase the immobile water in either the virgin or dried fibers appreciably although the hydrodynamic specific volume is increased due to other forms of associated water. This observation has implications in the interpretation of beating action and the effect is receiving further attention.

Concluding Remarks

Although the present experiments were designed only to relate wet-web properties to swelling, sufficient data have been examined to suggest that for purposes of further investigation the fiber properties which contribute to wet-web strength may be assumed to be (a) hydrodynamic specific volume of the fibers, (b) specific surface, (c) flexibility (compressibility), (d) fiber length, (e) delignification. An increase in any one of these factors tends to increase the tensile strength. The nature and amount of the associated water represents a variable superposed on this pattern which determines the *shape* of the strength development curve, so that a series of samples arranged according to strength may have somewhat different orders at different solids contents.

The extent and mechanisms of association of water with pulp fibers presumably could be of significance not only in relation to drainage, as has been shown by Ingmanson (*12*) and the development of web strength but also to wet pressing and drying. For example, Han and Ulmanen (*10*) have published data based on the hot-surface drying of a thick pulp sheet which indicate a constant rate of evaporation and a constant apparent thermal conductivity until the pulp layer next the drying surface reaches 40 to 45% solids. A further transition occurs when the layer next the drying plate reaches about 50% solids: the temperature gradient rises abruptly and the rate of shrinkage increases. On the basis of our results we would interpret the first point as due to a decrease in mobility of the associated water and the second to a cessation of liquid water movement near the hot surface.

The present results and observations are intended to provide the basis for future work. Although the methods employed (fiber-water equilibria, wet-web testing at low rates of elongation and static pressing) do not reproduce the high-speed, nonequilibrium drainage and deformation processes encountered in papermaking practice the present work nevertheless demonstrates the importance of the fiber-water association to the initial strength development and other web properties of interest in papermaking.

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Structure-Property Relationships in Synthetic Fiber Papers

R. A. A. HENTSCHEL

This paper summarizes the interrelationships of the physical properties of synthetic fiber papers with (1) the mechanical variables of fiber length, fiber diameter, and sheet basis weight; and (2) the physical properties of the fibers making up the sheet. The relationships between fiber length and diameter and the tensile and tear strengths of synthetic fiber papers are developed. Tensile strength rises as the fiber length increases, reaching a maximum value characteristic of the fiber used. The length at which the maximum is reached is shown to be dependent on the diameter of the fiber such that the smaller the fiber diameter, the shorter the fiber length at which the maximum is reached. Tear strength increases essentially linearly in the length region studied as the length increases, with the highest level of tear strength being associated with the largest fiber diameter. Tensile and tear strengths also rise to a constant level as the basis weight of the sheet is increased. Again the basis weight at which maximum strength is reached is dependent on fiber diameter. Paper tensile strength is shown to be linearly related to fiber tensile strength. Similarly, paper elongation at break is linearly related to fiber elongation at break.

REDUCED to its simplest terms, a sheet of paper can be thought of as a random aggregate of relatively strong fibers held together by a binder. On this basis, a systematic study of the structure—property relationships in papers should not be too difficult. On a purely experimental basis, one could systematically vary the morphology and properties of the fiber and the binder and establish relationships on the basis of these experiments. How far from the truth such an analysis is for cellulosic papers can be revealed by even the most cursory review of the literature on this subject. In a cellulosic system, the binder forms a part of the fiber and is developed by the complex interrelationships of hydration and mechanical action in beating. Simultaneously the morphology of the fiber is also varied. Thus, to sort out all the interactions becomes a nightmare.

In a synthetic fiber paper, on the other hand, we are forced to separate the two components of fiber and binder and handle them individually. Most synthetic fibers do not respond to beating as cellulose does due to their chemical and physical make-up. Consequently, synthetic fibers must be held together by some external binder system to make a sheet. Thus, there is an ideal opportunity to develop structure property relationships in a controllable and systematic way. The Du Pont Co. has been studying synthetic fiber papers for several years now, and in the course of this work, considerable experimental data bearing on these relationships have been accumulated. It is the purpose of this paper to summarize the effects of such variables as fiber length, fiber diameter, fiber strength, and elongation on synthetic fiber paper properties in the hope that these studies will shed some light by analogy on related variables in cellulosic sheets. These studies are all based on laboratory handsheet results, in many cases using experimental and commercially unavailable binder systems. They represent the results of many individual Du Pont workers drawn together in summary form. Since the emphasis in this paper is on qualitative relationships, very few numerical data will be given. We will not be concerned with the specific properties of papers made from nylon fiber or from "Dacron"* polyester fiber or from any other specific fiber, so much as with how properties in a general sense have been found to be related to sheet structure. Suffice it to say that quite a few man-years of effort have gone into gathering the numbers on which these relationships are based.

Let us go back to our original definition of a sheet of paper as a random array of strong fibers held together by a binder. On this basis, an hypothesis can be built up regarding sheet properties. The physical properties of a sheet as defined will be determined by three factors:

1. The structural arrangement of the fibers and the binder. This includes such factors as binder content, fiber length, fiber diameter, fiber orientation in the sheet, and fiber dispersion (or sheet formation).
2. The strength properties of the fiber.
3. The properties of the binder.

In analyzing the failure of a sheet of this sort, four failure conditions are possible: (1) the fiber ruptures, (2) the binder ruptures, (3) both fiber and binder rupture indiscriminately, and (4) the bond between fiber and binder ruptures.

In synthetic fiber technology, the maximum fiber properties are reached when the polymer molecules making up the fiber are oriented along the fiber axis. Most synthetic fibers are sold in the oriented condition. Binders, on the other hand, are normally used in the unoriented state and are therefore weaker than their oriented counterparts. Therefore, conditions which lead to fiber rupture will result in the highest level of properties in the sheet. The only requirements that the binder must then meet are: (1) to adhere sufficiently well to the fiber and have a high enough level of strength as an adhesive to assure fiber rupture, and (2) not interact with the fiber in such a way as to reduce fiber tenacity. If the binder successfully meets these conditions, then the properties of the sheet should become a direct function of the properties of the fiber from which it is made.

With this background, let us turn to the experimental work leading to a check on the foregoing hypothesis.

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* Du Pont trademark for its polyester fiber.

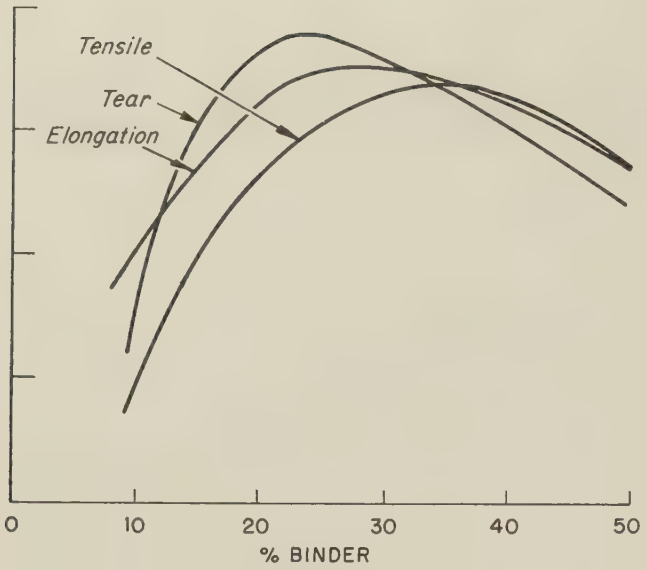

Fig. 1. Physical properties versus binder content

The first factor to be examined is the relationship between binder content and sheet properties. Figure 1 shows this relationship for tensile strength, break elongation, and tear strength. In this figure, the binder content is shown as per cent of the total sheet weight while the property axis is provided only with division lines indicating relative values. This arises from the fact that the binder content of the sheet at which maximum properties are reached has been found to be approximately the same for any fiber if a binder is used which causes fiber failure when the sheet is ruptured. The level of sheet strength, however, will be shown later to be dependent on the properties of the fiber from which it is made. Figure 1 shows the sheet properties to rise as the binder content increases, reaching a maximum, and then falling off. A moment's reflection will show that this form of relationship is to be expected. As the binder content rises, more and more fibers are tied together, each contributing its share to sheet strength. Thus, the sheet properties will rise as the binder content is increased. Ultimately, however, a point is reached where all the fibers are bonded together. Beyond this point, a further increase in binder content reduces the number of load bearing fibers contributing to sheet strength, and properties based on a constant sheet weight, as a result, fall off. It will be noted that break elongation peaks at a slightly lower binder content than tensile strength, and tear strength at a still lower binder level. The similarity of these curves to those obtained from paper stock beaten to various degrees is apparent.

The next variables to be considered are fiber length and fiber diameter. Their effect on sheet tensile strength is shown in Fig. 2. This shows that as fiber length increases, tensile strength rises to a maximum and then begins to fall off. It also shows that as the fiber diameter (denier) decreases, the fiber length at which peak strength is reached also decreases. However, the peak values of strength are essentially the same regardless of fiber diameter. The increase in strength as the length increases from zero is not unexpected. With very short fibers, the chances that individual fibers will not be bonded into the structure at or near both ends becomes much greater. Thus very short fibers do not properly contribute their strength to the sheet as a whole, and the sheet strength would be expected to fall off at short fiber lengths. As the fiber diameter decreases, it has been seen that the peak strength is reached at shorter fiber lengths. This arises because at a given sheet weight, as the fiber diameter decreases, the number of fibers in the sheet cross section increases. Thus, there is more opportunity for bonding, and consequently a lower length at which properties begin to fall off. It is also not unexpected that the maximum sheet strength is independent of fiber diameter when the fiber strength is held constant. However, the experimental fact that sheet strength falls off at longer fiber lengths is somewhat puzzling at first. It would be expected that once the fibers are effectively bonded into the structure along their whole length, that the sheet strength should become constant. On re-examining the sheets on which these results were based, it was observed that the sheet formation became increasingly poor at the longer fiber lengths. Thus, the fall-off in strength at long fibers lengths can be attributed to poor formation. This also explains why the fall-off in tensile at long fiber lengths is more severe with smaller fiber diameters. The finer the fibers, the more flexible they become, and

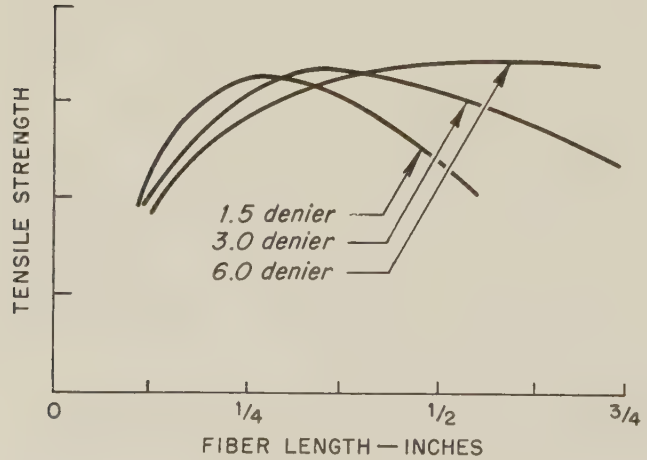

Fig. 2. Tensile strength versus fiber length and diameter

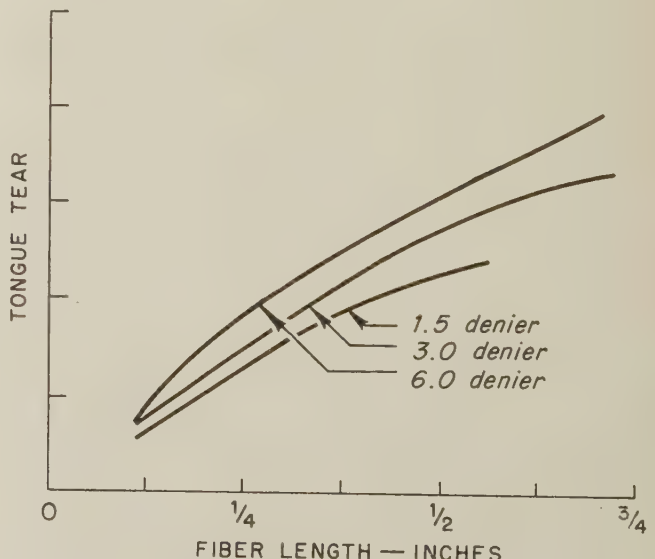

Fig. 3. Tear versus fiber length and diameter

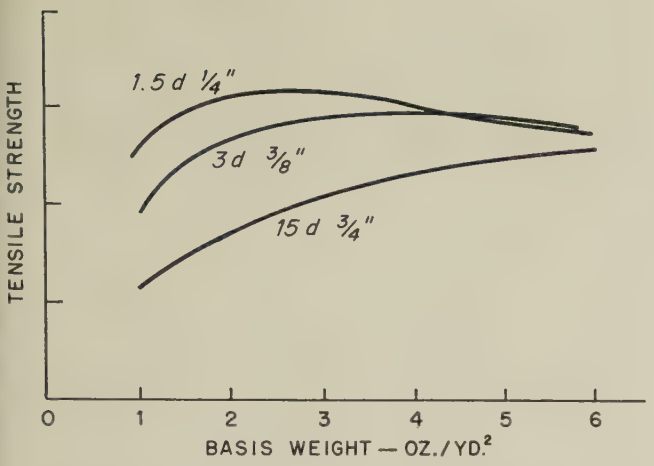

Fig. 4. Tensile strength versus basis weight

therefore the more opportunity there is for entanglement and resultant poor formation. This has been checked by using commercially impractical laboratory methods for making long-fibered sheets with good formation. With such well-formed sheets, the tensile strength becomes invariant with fiber length at longer lengths.

In tear strength, the relationships with fiber diameter and length, shown in Fig. 3 are somewhat different. The tear strength rises steadily with fiber length, tending to level off at a constant value at lengths beyond those included in this study. Sheet formation is not important to tear strength as it is to tensile strength. The tear strength also increases with fiber diameter at a constant fiber length. These relationships arise from the nature of the tearing process in which individual filaments, or small fiber bundles, fail more or less successively as the tear proceeds. Thus, the fiber with the highest individual filament strength (highest diameter) will give the highest tear values. Further, the fiber arrangement in the sheet (formation) becomes less important than in a test where all fibers must cooperate simultaneously as they must in the tensile test.

The effect of basis weight on sheet properties is shown in Figs. 4 and 5. For tensile strength, Fig. 4 shows that, starting at very low basis weights, sheet tensile strength increases as the basis weight increases, reaching a value at high basis weights which is essentially equivalent for all fiber diameters. The larger the fiber diameter, the higher the basis weight at which this equivalent tensile strength is reached. The fall-off in tensile strength at low basis weights starts at the point at which there are no longer enough fibers present to completely fill the sheet area. Thus, the lower the fiber diameter, the more fibers there are present and the lower the basis weight at which tensile begins to suffer.

Tear strength shows similar relationships with basis weight as shown in Fig. 5. Here, however, two additional phenomena are seen. First, as the basis weight is increased, the tear strength goes through a maximum and then levels off. The finer the fiber, the lower the basis weight at which this maximum appears. The reasons for the maximum are not understood, but may relate to the arrangment of the fibers in the sheet thickness. Second, the level of tear in the constant tear strength region depends on fiber diameter and length, the higher the denier and length, the higher the tear. This effect was noted earlier in Fig. 3. It is emphasized that the data for the effect of basis weight shown in Fig. 5 were obtained using the optimum fiber length for each diameter chosen from Fig. 2. Thus, in this case the level of tear reflects both the effects of diameter and length of the fibers.

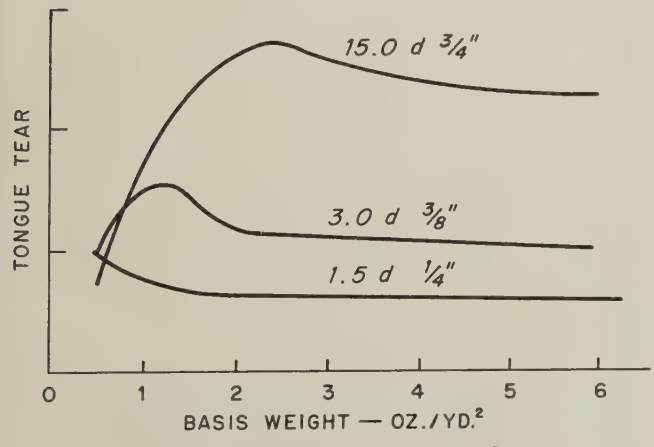

Fig. 5. Tear versus basis weight

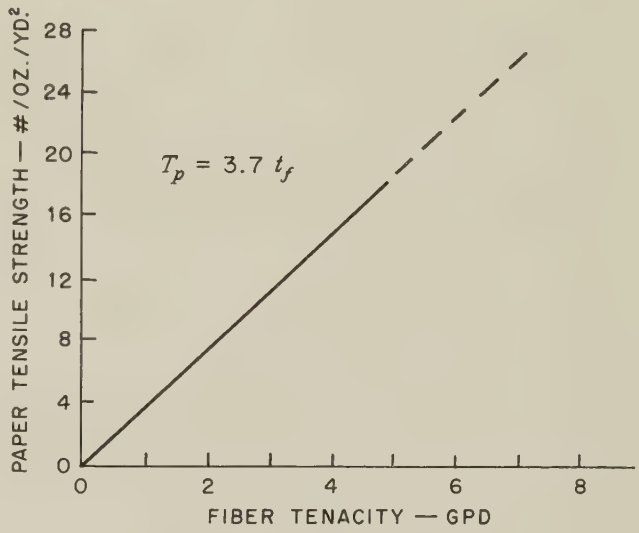

Fig. 6. Paper tensile strength versus fiber tenacity

In the preceding discussion, the mechanical factors of fiber diameter and length, sheet weight, and binder content have been considered for their effect on sheet properties. In the following section, the effects of fiber properties on sheet properties will be taken up. In these experiments, the factors of fiber, length, fiber diameter, binder content, and sheet weight have been held constant at 1/4 in., 3 denier, 25% and 2.5 oz. per sq. yd., respectively.

Figure 6 shows the relation between fiber tenacity and sheet tensile strength to be a straight line. Expressing this in mathematical form, the relation is:

$$Tp = 3.7 t_f$$

where

Tp = paper tensile strength in lb./in./oz./sq. yd.
t_f = fiber tenacity in grams/denier

Or, using the same units for both paper tensile strength and fiber tenacity:

$$Tp = 0.22t_f$$

It seems worth while to consider how this relationship was developed, and some of the consequences which follow. It was derived from a very large mass of data on nylon, "Orlon"* acrylic fiber, "Dacron" polyester

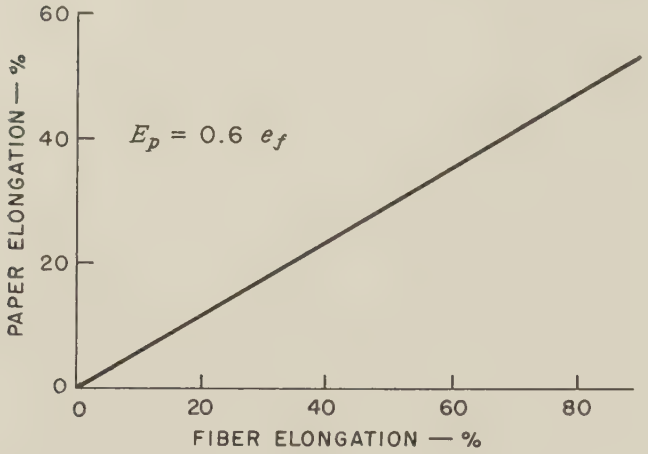

Fig. 7. Paper break elongation versus fiber break elongation

fiber, acetate, viscose, cotton and a number of experimental fibers, bonded with a variety of commercial and experimental binders. From these raw data, the highest reproducible paper strength achieved for each particular fiber was plotted against the corresponding fiber tenacity. In this way, a considerable number of points were plotted, all of which were found to fall on a straight line through the origin. Calculating the correlation coefficient for the data against this straight line gave a value of 0.987. Since a large variety of fibers in terms of both chemistry and physical properties are represented, this high correlation coefficient is strong, presumptive evidence for a valid functional relationship. Further, examination of the raw data shows many cases in which, for a given fiber, binders giving paper tenacities well below the line exist, but no cases in which there were fiber-binder combinations giving paper tenacities substantially above the line.

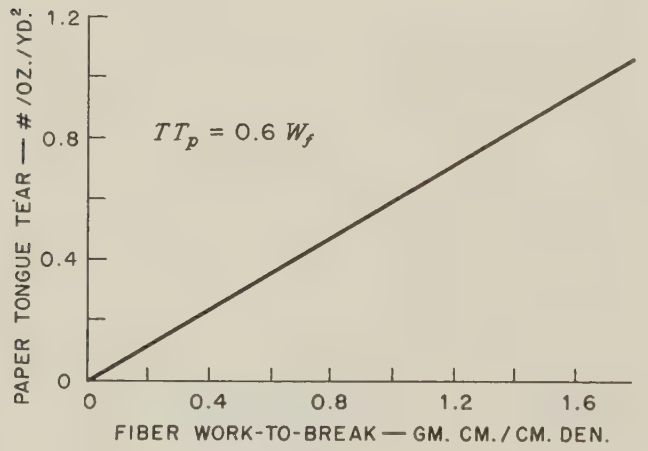

Fig. 8. Paper tear versus fiber toughness

While intuitively, the foregoing relationship seems reasonable, no theoretically derived relationship exists against which to check it. The nearest approach is to be found in work by Van den Akker† in which he derives analytically an expression for zero span tensile strength against fiber strength and gives experimental confirmation. In the zero span test, higher tensile strengths are expected—and measured—than in the normal tensile test with several inches span between the jaws. Van den Akker gives the relationship, using the same units for both paper and fiber strength, as:

$$Tpo = 0.375t_f$$

where

Tpo = zero span tensile strength of the paper
t_f = fiber tenacity

Van den Akker's coefficient of 0.375 for zero span tensile does not seem inconsistent intuitively with the experimentally derived coefficient of 0.22 given here for synthetic fiber sheets using results from the normal tensile test. Van den Akker's data for his best bonded sheet from unclassified southern pine pulp give a zero span tensile of 18.5 kg. per sq. mm. versus a normal tensile of 10.2 kg. per sq. mm. Using this ratio of 10.2/18.5 and converting the coefficient in his strength equation to relate the normal sheet tensile strength to fiber strength gives the coefficient a value of 0.21. The agreement with the coefficient of 0.22 developed for synthetic sheets is apparent.

A relationship between fiber break elongation and paper break elongation, given in Fig. 7, has also been experimentally derived. This is of the form:

$$Ep = 0.6e_f$$

where

Ep = paper break elongation, per cent
e_f = fiber break elongation, per cent

The correlation coefficient of the data used with this straight line was 0.938.

It has also been shown experimentally that paper tear strength, as measured by the tongue tear test used for fabrics, and fiber work-to-break are also related in a straight line fashion. This relation is shown in Fig. 8 and is expressed as:

$$TTp = 0.6\ W_f$$

where

TTp = paper tongue tear in lb./oz./sq. yd.
W_f = fiber work-to-break in g. cm./cm. denier

Considerably less data support this relationship, but a correlation coefficient of 0.908 was calculated. No justification can be given for this observation.

This paper attempts to correlate many of the factors which can be varied in making up a sheet of synthetic fiber paper with the physical properties of such a sheet. The correlations are largely empirical and it is hoped that future work will produce a theoretical framework which will adequately explain the observed effects. It is also hoped that these observations may help the much more complex study of cellulose pulp papers by showing the effects of controlled variations in many of the structural features going into the make-up of such sheets.

* Du Pont trademark for acrylic fiber.

†Van den Akker, J. A., Lathrop, A. L., Voelker, M. H., Dearth, L. R., "Importance of Fiber Strength to Sheet Strength", *Tappi* 41, pp. 416–425.

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Rate Phenomena in the Resin-Fiber-Water System

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Information on the rate and mechanism of take-up of wet-strength resins on papermaking fibers has been selected from the recent literature. Data relating to the three steps of molecular transport, adsorption, and surface reaction have been analyzed. Indications from these data are that the Donnan potential approximation for the electrical potential about the fiber (Neale) most adequately explains various isolated phenomena concerning the resin-fiber-water system. If this approximation is applied to one term of a diffusion equation presented by Kurath, Chu, and Swanson, the further indication is that the diffusional transport step is an important rate-controlling step in the overall reaction. Attention is drawn to the contribution of Steenberg in first elucidating this hypothesis.

STUDIES of rate phenomena and equilibria in resin-fiber-water systems have been hampered by the apparent heterogeneity of the reactions involved as well as by inadequate characterization of the components. Even in the case of the urea resins and the melamine colloid with which this paper is principally concerned, there are insufficient data on molecular structure and configuration to make even an educated guess of thermodynamic and kinetic behavior based on purely theoretical considerations. The situation with the cellulose part of the system is too well known to require comment at this point.

Analysis of rate effects in these systems therefore reduces to an essentially empirical study in which a studious attempt is made to conform to theoretically sound principles of interpretation. It is useful at this juncture to briefly review these principles and to comment on their application to the systems with which we are concerned.

One very common pitfall with paper systems is that of analyzing strictly *chemical* phenomena (or combined chemical reactions and transport processes) on the basis of *physical* effects produced. Specifically, it is not unusual to see references to rates of wet-strength resin take-up evaluated in terms of the rate of wet-strength development in the finished paper. The value of such information is very limited even to the person interested only in end results because the results depend upon the exact nature of the complete papermaking system employed. To the person interested in general interpretation, such results are useless. A *kinetic* study, whatever the degree of fundamental chemistry involved, can only be based on data relating to *chemical* composition.

Another well-known general principle of rate studies is that care must be exercised to distinguish strictly physical effects (physical adsorption, transport phenomena) from the kinetics of chemical reactions. In the classical general case of heterogeneous reactions, there are five rate steps in sequence, any one or a combination of which may determine the over-all rate of reaction. These steps are: (1) diffusion of reactant(s) from the bulk phase to the interface, (2) adsorption at the interface, (3) surface reaction of adsorbed material, (4) desorption of products, and (5) outward diffusion of products. Rate expressions and "energies of activation" may be determined for any of these steps, but only the surface reaction is strictly a kinetic phenomenon.

As will be discussed more extensively later, this general case must be modified somewhat to account for processes involved in resin take-up on cellulose fibers. The distinguished British chemist, S. M. Neale, suggests that fibers in water or dilute aqueous salt solution may be approximated by two homogeneous phases, the aqueous solution and the cellulose gel. Such a model greatly improves the interpretation of experimental results concerned with the thermodynamics of dyeing and, as we shall see, helps explain some recently observed phenomena in the resin-fiber-water system. However, because of the nature of the ionic atmosphere surrounding both resin particles and cellulose fiber, Neale's approach, while helpful, may not be sufficient for analysis of rate data in the systems of concern here.

RATE STUDIES ON WET-STRENGTH ADDITION

An early rate study of wet-strength addition was that of Steenberg (*1*) who observed that melamine acid colloid took up very rapidly on sulphate pulp beaten to 40°S.-R. and 1% consistency. In 1/2 min. the resin take-up had already reached about 60% of the more or less stable value found after 30 min. Later Henrickson and Steenberg (*2*) commented that the take-up of urea-formaldehyde (U-F) resin was so rapid that it was not possible to study the rate process in detail. Commenting on the well-known heterogeneity of the U-F resins, these workers indicated that the part *not rapidly* taken up on the cellulose was not very effective in producing wet strength. This point is highly significant in view of the role hydrogen bonding is thought to play in creating wet strength. Henrickson and Steenberg further remarked that no great difference in *retention* was observed among positive, negative, and essentially nonionic U-F resins, indicating (in their view) that the charge on the fiber does not play much of a part in the retention of U-F resins. Fineman and Gruntfest (*3*) subsequently published evidence conflicting with that of Henrickson and Steenberg but commented that the tendency to form OH···N bonds could account for nonspecific bonding.

Quite recently, two papers on rate studies of resin adsorption have been published based on work sponsored by TAPPI and The Institute of Paper Chemistry. In both of these studies, the concentrations of fiber and resin were kept quite low so that measurably slow rates could be obtained. Thode, Swanson, Kurath, and Hoffman (*4*) showed that the "energy of activation" of the initial melamine colloid take-up on sulphite pulp

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was 5600 cal. per mole. Similarly, Kurath, Chu, and Swanson (*5*) demonstrated that the activation energy for initial take-up of a cationic urea-formaldehyde resin was 5200 cal. per mole. This rather low value of activation energy strongly suggests that a physical process is the rate-controlling reaction. However, the rate of formation of a single OH···N bond could still be of importance, since OH···N bond energies lie in the range of 4000 to 7000 cal. (*6*).

Before closing this brief survey of previous work on the specific subject of wet-strength resins, let us note the results of Maxwell and Reynolds (*7*). These workers showed a very interesting relationship between the retention of melamine hydrocolloid and addition of ionized salts which consisted of an initial rapid rise in retention with salt concentration followed by drop-off as salt content is still further increased.

Qualitatively at least, the facts on melamine (and probably urea) resin take-up may be summarized as follows: The initial rate of resin take-up is very rapid indeed, so that it is necessary to go to very dilute conditions of 0.01% consistency to get conveniently measurable rates. Increasing either the melamine or the fiber concentration greatly increases the rate. Within limits, increasing the salt concentration increases the take-up. (This is probably a matter of rate.) Increasing the temperature increases the rate.

THE MOLECULAR TRANSPORT STEP

Because the evidence concerning the temperature effect on rate points to the importance of a molecular transport step, Kurath, Chu, and Swanson (*5*) went to some detail in analyzing the possibilities. They present the following equation for the rate of transport of polyelectrolyte molecules toward the fiber:

$$j = -\frac{R_s \partial U(x,t)}{\beta \partial x} - D\frac{\partial R_s}{\partial x} \qquad (1)$$

where

j	=	diffusion current in the x direction, g. per sec. per sq. cm.
D	=	diffusion coefficient
β	=	a friction coefficient
$U(x, t)$	=	potential field about the fiber due to its charge
R_s	=	concentration of resin in solution

An analysis of the first term on the right side of this expression may be of considerable speculative interest.

Probably the most satisfactory theoretical analysis of the potential field around a charged polymer particle (or fiber) is that of Wall and Berkowitz (*8*). These writers employed a numerical solution to the Poisson-Boltzman equation for several models of dispersed polyelectrolytes. In one of these models, a parameter R is defined by assuming N polymer molecules present in V cc. of solvent, whence

$$(4/3)\pi R^3 = V/N \qquad (2)$$

The interpretation of experimental data on the basis of this model is not yet possible with fiber systems. However, it may be noted that at high initial charge densities, the assumption that, electrically speaking, the polymer molecule and its bond solvent make up one homogeneous phase and the free solvent the other is not at all bad.

Neale (*9*) has made this simplifying assumption with regard to cellulose fibers and has analyzed experimental data concerning uni-univalent electrolytes and dye ions, taking into account the Donnan equilibrium. In their classic paper on the subject, Neale and Standring (*10*) distinguish between this equipotential volume model and the older one in which the charge on cellulose is considered to reside on the surface. They explain that if the fiber is regarded as a homogeneous phase containing a concentration, H, of immobile anions, the phase *potential difference*, ψ, should vary with the external concentration, m, of uni-univalent electrolyte according to the relation,

$$\psi = \frac{RT}{F}\sinh^{-1}\frac{A}{2m} \qquad (3)$$

They demonstrated that experimental data on Donnan potentials of cellophane agreed quite well with this equation in contrast to poor agreement with the analogous equation for the surface model.

These data of Neale and Standring show that the Donnan potential on cellophane is very high at low salt concentrations and decreases with increasing salt concentration. The Donnan potential increases with increasing carboxyl content of the cellulose and decreases with pH of the external phase, going to zero at pH 2.5. This drop in potential with pH is attributed to repression of the ionization of cellulose. Later work by Neale and Saha (*11*) showed that dyeing of the cellophane changed the Donnan potential in accord with valence and concentration of the sorbed dye ion.

Qualitative application of the Donnan potential concept provides a unified interpretation of a number of previous, unrelated observations concerning wet-strength resins. For example, Steenberg (*1*), at a time when the surface (or *zeta*) potential model was still in favor, suggested that the evidence then available indicated that melamine colloid was coagulated on the fibers in much the same way it was flocculated by electrolytes. He cited very high melamine take-up on oxidized sulphate pulp, known to have many uronic acid groups. Compare this with the high Donnan potentials found on oxidized cellophane by Neale and Standring (*10*).

The importance of a volume model may explain the linear dependence of initial rate of melamine take-up on the swollen specific volume of the fibers as reported by Thode, Swanson, Kurath, and Hoffman (*4*). The salt effects reported by Maxwell and Reynolds (*7*) and the low affinity of melamine for alpha pulp are likewise explainable in terms of Donnan potentials. That is to say, returning to equation (1), that the first term on the right is important in determining rate and that $\partial U/\partial x$ can be approximated in terms of some function of ψ, the Donnan potential.

Earlier in this section, one possible justification for approximating $U(x, t)$ in terms of ψ was advanced. Before leaving the topic, an important obstacle to such approximation must be mentioned and the corollary point of a temperature coefficient on the expression discussed.

While Neale's model is a reasonable approximation of the Poisson-Boltzman distribution in the case of cellophane or even in the case of unbeaten fibers, it must, at least, be modified by the presence of fibrils on the usual papermaking fibers. Although the parent fiber, plus possibly some of the fibrils, may be regarded as an equipotential volume, experimental evidence such

as that obtained by Goring, Biefer, and Mason (*12*) clearly shows that some fibrils move in an applied electrical field with resultant polarization of the system. It is thus apparent that as a charged polyelectrolyte molecule approaches a beaten fiber in suspension, the field surrounding the fiber is altered by the influence of the field of the approaching particle. It is influenced in a rather peculiar sort of way because actual movement through solvent of the fibrils may take place. The energy involved is primarily related to the viscosity of the solvent and thus would be of the order of the 5100 cal. per mole calculated by Kurath, Chu, and Swanson (*5*). To be realistic, however, it should be pointed out that the mass of the fibrils is much larger than that of the melamine particles, with the result that none too great fibril movement is to be expected.

Two points are clear from this: (1) If the molecular transport step is established as the rate-controlling step in resin take-up, still further evidence is required to separate the effects of Fick's law of diffusion and the effects of the electrical field; (2) In evaluating $\partial U(x, t)/\partial x$, it must be borne in mind that the potential field around the fiber is likely to be modified according to both the *position* and the *velocity* of the approaching particle.

PHYSICAL ADSORPTION STEP

In the system here considered, it may not be possible to distinguish between physical adsorption (concentration of resin at the fiber-water interface) and subsequent surface reactions, either strictly within or among resin particles or between resin and fiber constituents. Pure physical adsorption is concentration reversible, but experiments on the melamine colloid adsorption on cellulose showed no such reversibility (*1*). It would appear that some primary surface reaction is not appreciably slower than the adsorption step. Therefore, it must be concluded that physical adsorption, as distinguished from even so low-energy reaction as hydrogen-bond formation, must be ruled out as a rate-controlling step in these systems.

SURFACE REACTION STEP

It is important to the desired understanding to discover if the surface reaction is rate-controlling or approximately equal in rate to the transport step. Also, we should know whether the reaction takes place at single or multiple sites. Dye take-up, for example, is believed to take place on multiple sites, but such is not thought to be the case for melamine colloid take-up because of the low activation energy observed. Nevertheless, this point should be experimentally checked for two reasons: (1) because of the uncertainty in the definition of a mole, kinetically speaking, in this case, and (2) because one possible structure of the melamine polymer yields a distance between imido nitrogens in adjacent melamine rings of 10.2 A. One such experiment would be to measure initial rates at constant low fiber consistency but increasing melamine concentration. If surface reaction at single sites is controlling, the plot of rate of initial take-up will at first rise rapidly with increasing resin concentration but will later level off to a constant value. If reaction at duel sites controls, the above plot will pass through a maximum dropping off as competition for sites begins to interfere with proper reaction. Up to the limit of concentrations studied, the urea resin data of Kurath, Chu, and Swanson do not show either trend. It should be pointed out that resin flocculation may interfere with such an experiment.

If a chemical reaction at the surface controls or is important, there is much to indicate that the OH $\cdots$ N bond is what determines the specific affinity. It is interesting to note that in the case of melamine colloid, the presence of internal hydrogen bonds (with unreacted methylol groups) makes multiple bonding of a given colloid particle to the fiber of low probability. However, after cure, the number of metholyl groups is presumably greatly reduced and there should be a number of places on the surface of a resin particle where double-bonded nitrogens are separated by 10.2 A., very nearly the 10.3A. identity period of cellulose.

THE RATE-CONTROLLING STEP

Possibly there will always remain some uncertainty as to the rate-controlling step, although, even without further experimentation, evidence points to the molecular transport step. An experiment such as that reported by Russo and Thode (*13*) on locust bean gum (LBG) adsorption could help. In that study, the initial rate of LBG imbibition was found to be a function of the stirrer speed in the sorption bath. Only the diffusion step could be so affected. In spite of such evidence, the rate of hydrogen-bonding surface reaction could be approximately that of the transport step, so that one or the other may control, depending on external conditions.

All in all, however, the assembled evidence indicates that the diffusional transport step plays a major role in controlling the rate of wet-strength resin take-up on cellulose fibers. Furthermore, it is fairly certain that the potential gradient term in the diffusion expression is of principal importance. Quantitative evaluation of this term is seen as the next critical step in our understanding of the phenomena in question. Borje Steenberg is to be commended on his vision for stating this so clearly 13 years ago, before most of the presently reviewed information was known!

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Fiber Surface Area and Bonded Area

JOHN W. SWANSON and ANTHONY J. STEBER

The linear correlation between optical scattering coefficient and nitrogen adsorption surface area of paper, first shown for a single pulp by Haselton (*12*), has been demonstrated for three other papermaking pulps of widely different characteristics. The proportionality constant relating the two properties was used for calculation of absolute bonded area of the papers. It is possible to isolate the relationship between bonded area and tensile strength of a sheet of paper. The data indicate that bond density (bonding strength per unit bonded area) increases with the degree of beating. The assumption of Ingmanson and Thode (*13*) of the constancy of the dry fiber surface area available for fiber bonding, was examined and found to be of doubtful validity for purified pulps.

THE surface or interface which divides any two immiscible or insoluble phases of matter possesses somewhat different properties than other parts of the system. The reason for this is that the surface atoms and molecules in solids and liquids have greater free energy than similar molecules within the bulk of each phase. This surface free energy tends toward a minimum as in all thermodynamic systems and is manifested in surface tension, adsorption, absorption, adhesion, flocculation, and many other surface phenomena. The total surface free energy in a particular system is the product of the specific surface free energy (surface energy per unit area) and the surface area. In a two-phase system where the specific surface area (surface area per gram) is high, surface properties become especially evident because the surface energy is an appreciable fraction of the total energy of the molecules in the system. This is one of the distinguishing features of the colloidal state of matter.

Although very little attention has been given to the measurement of the specific free surface energy or surface tension of cellulose fibers much work has been done on the determination of the surface area of fibers. It is well known that surface area is related to a great many pulp and paper characteristics even though this relationship is somewhat obscure in many instances. In the wet state, surface area of pulp fibers affects drainage rate, fiber flocculation and retention of fiber fines, sizing agents, adhesives, pigments, and dyes. In the dry state, surface area of fibers is related to optical properties, porosity, fiber bonding, filtration properties, and printing characteristics.

Numerous methods have been developed for determination of surface area. Among these are the geometric method, the surface catalytic or silvering method, gas and solute adsorption, gas and liquid permeability methods, radiochemical methods, and the optical methods. Several discussions of these methods have been published (*1*, *2*), the most recent of which is that of Thode and Ingmanson (*3*).

Paper has sometimes been described as a network of fibers and fibrils which are held together by surface forces. Modern theories of adhesion support this idea. The relationship between fiber surface area and paper strength has long interested papermakers. It is to be expected that increased surface area should afford greater opportunity for contact between fibers and for interaction of surface forces. The primary questions which arise concerning this relationship are—what type of surface area is significant and how should it be measured? The results obtained with many of the methods mentioned above agree quite well for smooth, uniform, well-defined surfaces. However, cellulose fiber surfaces are apparently quite irregular and much more difficult to define, particularly when the fibers are beaten and swollen in water. During the beating operation the fibrillar structure is unravelled and subdivided thereby exposing new surface which may differ appreciably in chemical composition from other parts of the surface (*4*). In addition to the external surface area there is a much larger internal surface area which becomes even larger as fiber swelling increases. There is also the lumen area to be considered. Only part of these "surfaces" may be important to a particular papermaking property and it is therefore necessary to choose methods which measure the significant surface. A further difficulty is inherent with the methods themselves. With the possible exceptions of the geometric and optical techniques, the methods of surface area measurement depend upon bringing another substance into contact with the fiber surface. Thus, the value obtained depends upon the availability of the surface to the substance being used to measure the surface area. All these uncertainties have contributed to the difficulty of establishing relationships between surface area and strength properties.

Mason (*1*) was among the first to note that external specific surface area of fibers as measured by the silvering or permeability methods does not correlate well with strength properties of paper. Earlier, however, Parsons (*5*) had noted that during the early stages of beating, the tensile strength of handsheets varied linearly with the area of fiber in optical contact. Ratliff (*6*) later made a further study of Parson's technique and confirmed that bonded area is approximately a linear function of beating time and that tensile and bursting strengths increased approximately linearly with bonded area. The slope of Ratliff's curve was very close to one, that is, doubling the bonded area also doubled the bursting strength. Following the early stages of beating, the rate of increase in strength fell off presumably because of increased fiber failure, or decreased fiber strength. Kenney (*9*) and Leech (*10*) also used this optical method for studies of paper strength. All of these investigators used optical measurements which were calibrated by means of the Clark silvering method (*7*, *8*) which involves boiling the

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fibers in aqueous ammoniacal silver nitrate solution. The relationship between the wet specific surface and the dry fiber surface area has never been clarified. Furthermore, the scattering coefficients for the completely unbonded fibers were determined on sheets dried from butanol—a procedure which is now known to yield too high values because of the intrafiber light scattering. It is not surprising, therefore, that the bonded areas obtained were rather high, particularly those values obtained for the sheets made from unbeaten pulps. However, the concept of comparing strength properties of paper in terms of bonded area is sound and development of a suitable method would be very useful. Such a tool would make possible the isolation of the factor of degree of fiber bonding from such factors as individual fiber strength, specific strength of the bond, distribution of bonds (formation), and other properties of the pulp.

A significant advance was made in this field when Haselton (*11*, *12*) proposed the use of gas adsorption as a method of exploring the surface area and bonded area of papers. The nitrogen molecule, which was the principal adsorbate used, has a diameter of 4.3 A. and would be expected to penetrate into regions which might not be measured by other substances or by scattering of light. Furthermore, this distance is of the order of the length over which true molecular bonds occur. Thus, the doubts about the errors in the optical method could at last be checked. Haselton demonstrated that there is an excellent correlation between the specific scattering coefficient of unbleached sulphite handsheets dried from water and the area obtained by adsorption of nitrogen. He was further able to show that the scattering coefficient of handsheets dried from organic solvents was much too high. After comparing bonded areas calculated by four methods he concluded that a value closest to the true bonded area could be obtained by applying a correction factor to the regular optical values.

In a more recent paper concerned with factors contributing to the strength of a sheet of paper, Ingmanson and Thode (*13*) made an examination of the available methods for determination of bonded area and proposed a new method for securing *relative* bonded area. They demonstrated that at the same bonded area, *ball-milled, classified* pulps from which the fines had been removed have the same strength properties as unclassified (whole) pulp. Their studies led to the conclusion that the total *dry* fiber area available for fiber bonding which is effective in developing sheet strength remains constant with refining time, and is unaffected by production of fines or the degree of fibrillation. These workers suggested that if Haselton's correlation between specific scattering coefficient and nitrogen adsorption surface area holds for other papermaking fibers this method would have considerable promise as a tool for characterization of pulps.

Briefly, Ingmanson and Thode's method for securing *relative* bonded area from light scattering measurements is based on the following ideas:

1. The specific scattering coefficient, s_u, of a sheet dried from water in the normal manner varies linearly with the exposed or unbonded fiber surface area, A_u, according to the following equation

$$S_u = kA_u + i \qquad (1)$$

where s_u is the specific scattering coefficient of the sheet of paper, and A_u is the unbonded surface area determined by nitrogen gas adsorption, and k and i are constants.

2. The specific scattering coefficient of totally unbonded fibers s_t, bears a similar relationship to the total possible exposed fiber surface area A_t,

$$s_t = kA_t + i \qquad (2)$$

This is simply a special case of equation (1).

3. The total *dry* fiber surface area available for fiber bonding which is effective in developing tensile strength remains constant with refining time and is unaffected by production of fines or the degree of fibrillation. This assumption permits extrapolation of a plot of s_u versus tensile strength to zero tensile strength to obtain s_t.

4. The specific scattering coefficient s_u, can be determined from reflectance measurement R_0, the reflectance of a single sheet backed by a black cavity, and R_∞, the reflectance of a sheet backed by a thick pad of the same material, by referring to tables or charts which contain the relationships between these values and the scattering power sW, according to the Kubelka-Munk theory. Knowing the basis weight, W, of the specimen permits calculation of s_u [see Van den Akker (*14*)]. The reflectance values are made with monochromatic light. Suitable charts have been prepared by Judd (*15*), by TAPPI (TAPPI Data Sheet 65), and by the Physics Department of The Institute of Paper Chemistry.

Then since the absolute bonded area A_b, is by definition the difference between the total possible surface area A_t, and the unbonded surface area A_u,

$$A_b = A_t - A_u = (s_t - s_u)/k \qquad (3)$$

or

$$kA_b = k(A_t - A_u) = s_t - s_u \qquad (4)$$

where the quantity kA_b, is proportional to the bonded area.

The relative bonded area then becomes

$$A_b/A_t = \frac{s_t - s_u}{s_t} \qquad (5)$$

Ingmanson and Thode found that tensile strength, z-tensile strength, tear factor, folding endurance, and apparent density data for classified and unclassified ball-milled pulps fell on the same respective curves when plotted against relative bonded area.

These workers pointed out that the most promising method of transposing relative bonded area into absolute values of bonded area might be through relating optical data to absolute areas as measured by gas adsorption techniques. This would permit calculation of A_b, from equation (3). The work of the present paper was done to examine this possibility and it constitutes a further progress report on studies of factors contributing to the strength of a sheet of paper.

Haselton (*12*) had obtained an excellent correlation between the specific scattering coefficient and surface area of water-dried handsheets as measured by application of the Brunauer, Emmett, and Teller (BET)

equation (*16*) to nitrogen adsorption isotherms. A linear relationship was found. The slope of such a line provides the k value of equation (3) for that particular pulp. The first step of the present study, therefore, was to establish the generality of such linear relationship and to appraise the variation of k for several widely different pulps.

EXPERIMENTAL PROCEDURE

Sample Preparation

The pulps used in this study were subjected to the controlled variables of refining time and wet pressure applied to the handsheets. A laboratory Valley beater was employed with refining intervals of 0, 20, 50, 90, and 180 min. The refined pulps were screened in a Bauer-McNett classifier employing a 150-mesh screen to remove fines. Handsheets were prepared, using a British handsheet mold, and were dried on chromium-plated disks and drying rings at 73°F. and 50% R.H. Groups of the handsheets were wet pressed at 0, 1, 10, 25, 50, and 150 p.s.i.

Physical Tests

The apparatus for nitrogen adsorption determinations was of the Harkins-Jura (*17*) type and was similar to that described by Haselton (*11*). The "dead space," the space not occupied by sample and capillary tubing, was measured using helium. The adsorption isotherm was obtained by allowing known volumes of nitrogen gas to enter the sample tube and reach equilibrium pressures. The dead space and surface area measurements were both made with the sample tube immersed in liquid nitrogen. Each surface area was determined from not less than three points on the isotherm between relative pressures of 0.05 to 0.30. Each surface area was measured twice and the average was taken as the surface area used in subsequent calculations.

Fifteen handsheets were employed for the B.E.T. surface area measurement (approximately 19 g.). In the interest of decreasing the dead space in the sample tube and preventing damage to the handsheets when placing them in the sample tube, small disks, measuring 23 mm. in diam., were cut out of the handsheets. This was done with an Arch punch. The disks were dried in a vacuum desiccator over magnesium perchloride for 72 hr. They were then sealed in a glass sample tube and attached to the gas adsorption apparatus and out-gassed overnight.

Scattering coefficients were determined at three different wavelengths—450, 550, and 650 mμ. The G.E. recording spectrophotometer (GERS) was used.

Tensile strength values were obtained for the handsheets using TAPPI Standard T 404 m-50.

RESULTS AND DISCUSSION

Experimental work has been completed on three different pulps—a coniferous bleached sulphite (hemlock, 80 to 90%; fir 10 to 20%, larch, trace), coniferous unbleached kraft (Douglas-fir, hemlock), and a bleached gum sulphate. The B.E.T. area, specific scattering coefficient at three wavelengths of light, and tensile strength data are presented in Tables I–III.

The specific scattering coefficient was plotted versus nitrogen adsorption area for the three wavelengths at which scattering coefficients were determined. Typical plots for the three pulps are shown in Figs. 1 through 3. It is apparent that a good linear correlation exists between nitrogen adsorption area and specific scattering coefficient in each situation. Thus, Haselton's correlation has been confirmed for three additional pulps of widely different characteristics. The k values, which are the slopes of these linear plots, were calculated by the method of least squares. The slopes and intercepts are presented in Table IV. The k values vary with

Table I. B.E.T. Area, Scattering Coefficient, and Tensile Strength Data for Weyerhaeuser Bleached Sulphite Pulp Handsheets

Refining interval, min.	*Wet pressing, p.s.i.*	*B.E.T. area, sq. cm./g.*	*Scattering coefficient, sq. cm./g.* 450 mμ	550 mμ	650 mμ	*Tensile strength, lb./in.*
0	0	6440	299	291	282	2.7
0	1	6640	316	300	290	3.9
0	10	6040	308	299	291	5.9
0	25	5240	286	280	272	7.5
0	50	4470	255	248	238	9.8
0	150	4390	204	199	191	13.6
20	0	5600	275	263	258	13.2
20	1	5260	255	246	238	18.6
20	10	4530	235	225	218	21.5
20	25	3990	218	210	202	20.9
20	50	3940	196	189	181	23.4
20	150	3700	160	152	146	25.5
50	0	4350	232	225	218	24.1
50	1	4260	209	202	195	25.8
50	10	3760	179	171	165	27.3
50	25	3140	170	164	158	28.5
50	50	3040	148	143	136	30.4
50	150	2430	119	114	109	29.1

Table II. B.E.T. Area, Scattering Coefficient, and Tensile Strength Data for Bloedel Standard Unbleached Kraft Pulp Handsheets

Refining interval, min.	*Wet pressing, p.s.i.*	*B.E.T. area, sq. cm./g.*	*Scattering coefficient, sq. cm./g.* 450 mμ	550 mμ	650 mμ	*Tensile strength, lb./in.*
0	1	7980	254	303	312	0.85
0	50	7000	238	262	266	1.70
0	150	7520	253	293	298	1.35
20	1	6580	222	257	261	7.40
20	50	4500	173	188	193	9.80
20	150	5440	192	204	209	9.40
50	1	6480	213	236	241	10.00
50	50	4950	173	188	192	12.20
50	150	4970	172	187	191	12.20
90	50	5280	167	182	187	14.40
90	150	4660	152	165	169	15.00

Table III. B.E.T. Area, Scattering Coefficient, and Tensile Strength Data for Coosa Bleached Gum Pulp Handsheets

Refining interval, min.	*Wet pressing, p.s.i.*	*B.E.T. area, sq. cm./g.*	*Scattering coefficient, sq. cm./g.* 450 mμ	550 mμ	650 mμ	*Tensile strength, lb./in.*
0	0	7350	329	329	320	0.46
0	1	6280	343	342	333	0.90
0	10	6700	346	343	333	2.02
0	25	6040	342	335	326	2.37
0	50	6260	338	332	321	2.85
0	150	5890	294	288	279	4.90
20	0	7030	340	336	325	4.30
20	1	6740	326	322	310	6.00
20	10	6190	323	319	304	8.10
20	25	6640	312	309	296	9.40
20	50	6260	302	295	283	9.70
20	150	5460	260	255	243	11.00
50	0	7360	321	317	306	8.70
50	1	6810	323	319	307	11.40
50	10	6880	302	297	283	15.80
50	25	5720	288	282	270	16.90
50	50	6220	284	276	265	17.90
50	150	5180	246	239	229	16.30
180	50	4080	191	187	179	...
180	150	3280	163	159	151	...

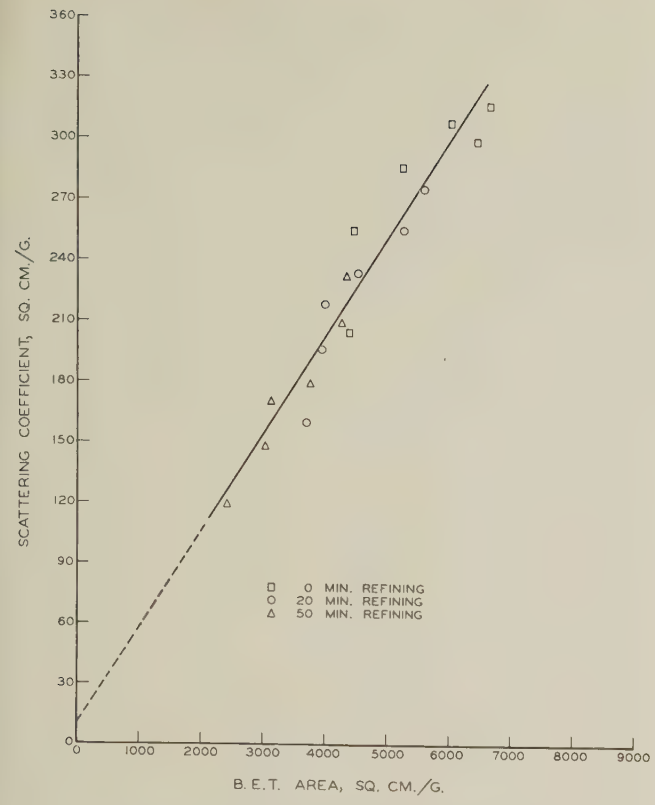

Fig. 1. Specific scattering coefficient versus B.E.T. area at 450 mμ for Weyerhaeuser bleached sulphite pulp

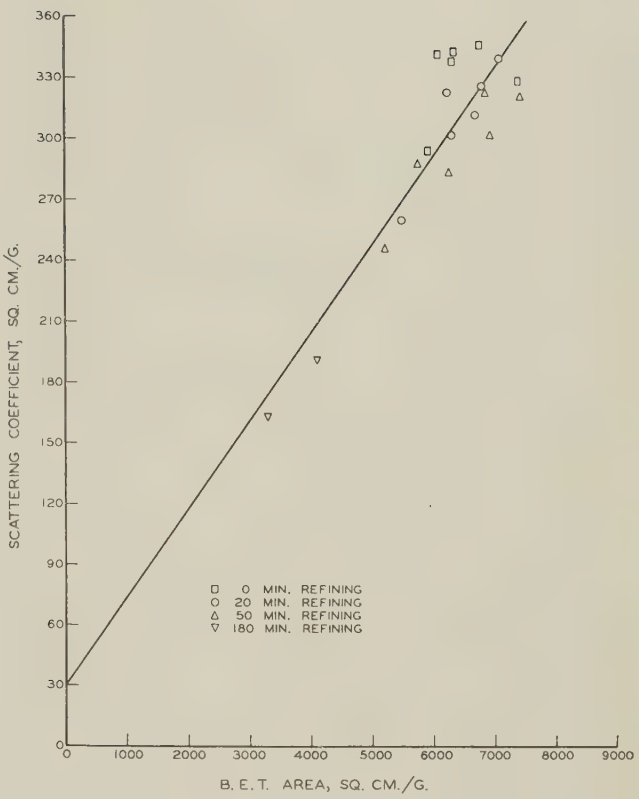

Fig. 3. Specific scattering coefficient versus B.E.T. area at 450 mμ for Coosa bleached gum pulp

the type of pulp but seem to approach a similar value of 0.044 at higher wavelengths of light (see Fig 4). Van den Akker (*18*) has made the interesting observation that 0.044 is approximately the value which would be expected by application of Fresnel's law of reflection to a diffusely reflecting body of randomly oriented fibers.

The straight line in each case is observed to intercept the scattering coefficient axis at a small finite value. In most cases this intercept value is positive; however, in a few cases a negative intercept appears. Haselton (*12*) found a small negative value for 100% bonded area, that is, when A_u was equal to zero. He accepted the validity of this value on the basis of the fact that, at 100% bonded area, light would still be scattered at the two surfaces of a sheet of paper. No specific explanation can be offered for the positive intercept values at this time except to call attention to the fact that the statistics become much poorer at lower values

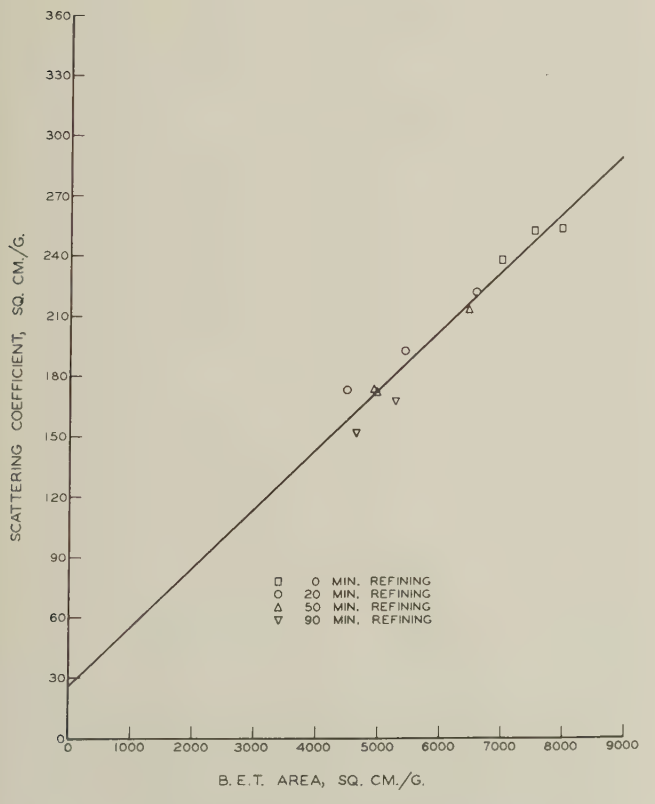

Fig. 2. Scattering coefficient versus B.E.T. area at 450 mμ for Bloedel unbleached kraft pulp

Table IV. Proportionality Constant, k, Intercept Values, i, and Unbonded Specific Scattering Coefficient, s_i, for Pulps at Three Wavelengths of Light

Wavelength, mμ	k	i	s_i, *sq. cm./g.*
Weyerhaeuser Bleached Sulphite Pulp			
450	0.048	10.4	321
550	0.046	9.7	309
650	0.045	5.6	300
Bloedel Standard Unbleached Kraft Pulp			
450	0.029	26.1	258
550	0.039	−6.6	306
650	0.040	−5.6	314
Coosa Bleached Gum Sulphate Pulp			
450	0.044	29.9	348
550	0.044	22.3	346
650	0.044	16.6	337

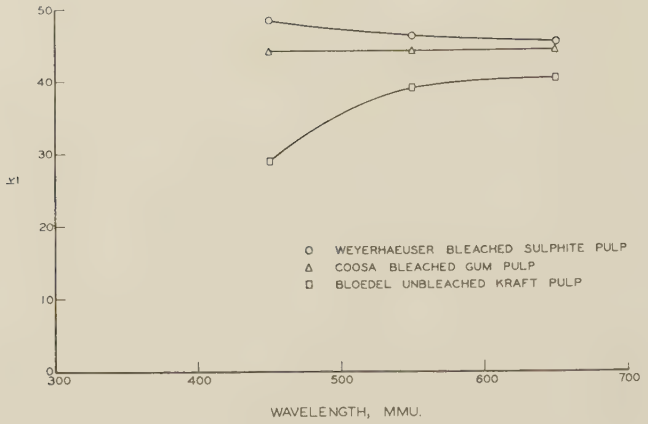

Fig. 4. Effect of wavelength of light on the k constant

for the gas adsorption surface area. Quite possibly more precise measurements would cause the line to pass very close if not through the origin.

As recommended by Ingmanson and Thode (*13*) plots of specific scattering coefficient versus tensile strength were made and the curves were extrapolated to zero tensile strength to secure the scattering coefficient for totally unbonded fibers (s_t). These curves are presented in Figs. 5 through 7. The s_t values are summarized in Table IV.

The data of Ingmanson and Thode for *ball-milled, classified* pulp at all degrees of refining and wet pressing formed a common curve which could be extrapolated to zero tensile strength quite easily. The data of the present work for pulps which were beaten in the Valley beater, scatter, so that some uncertainty exists in the determination of s_t. Possible reasons for this will be discussed later. In the present work the data points

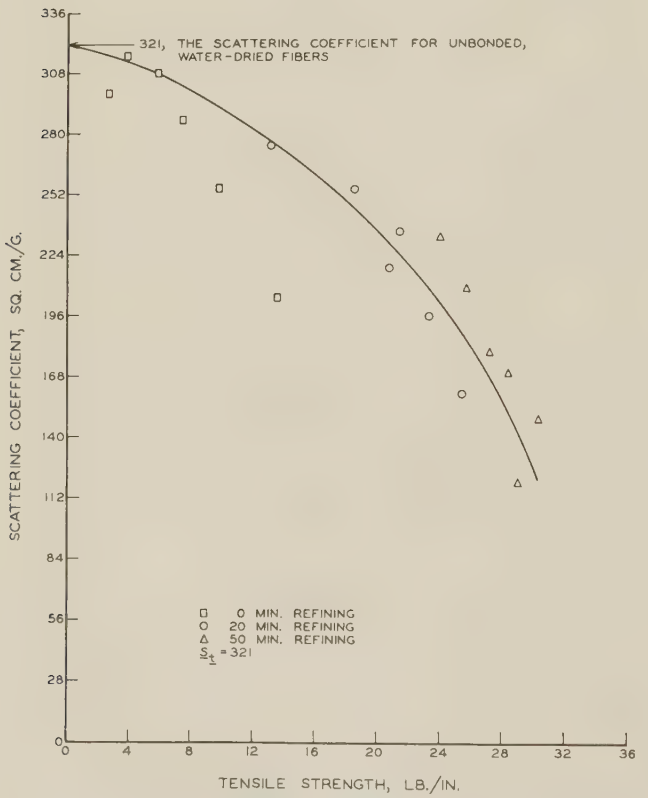

Fig. 5. Scattering coefficient versus tensile strength at 450 mμ for Weyerhaeuser bleached sulphite pulp

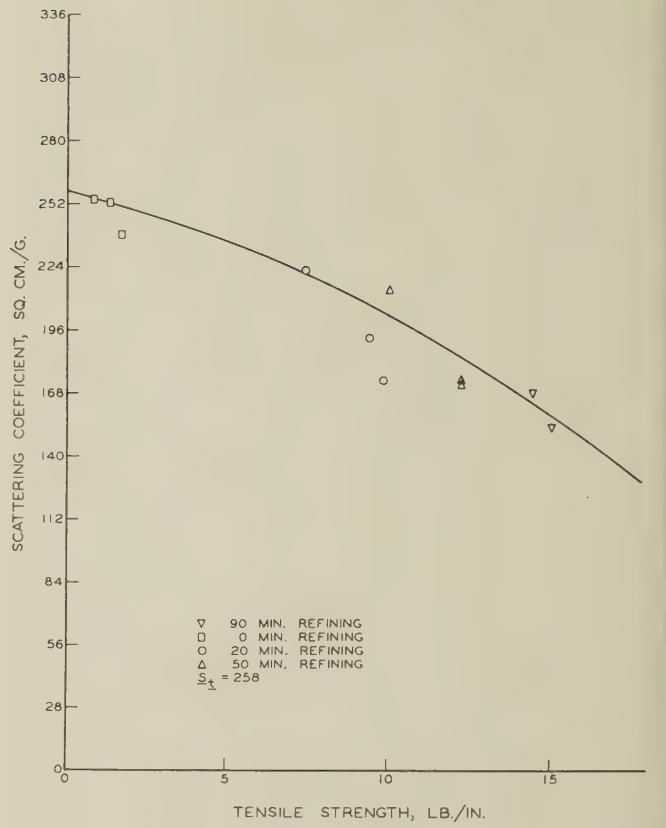

Fig. 6. Scattering coefficient versus tensile strength at 450 mμ for Bloedel unbleached kraft pulp

for the intermediate degrees of wet pressing were used in drawing the curved line for extrapolation. The derived values secured from the graphs are in Table IV.

The absolute and relative bonded areas of the handsheets calculated by means of equation (3) are recorded in Table V. The calculated values are shown to be consistent for the three wavelengths of light at which the scattering coefficient was determined, in spite of the basic change of scattering coefficient with value of wavelength. Generally, the bonded area did not change significantly with wavelength for the bleached sulphite pulp and the unbleached kraft pulp, but there appears to be a small but consistent increase of bonded area with wavelength for the hardwood pulp. Possibly this implies that the area in

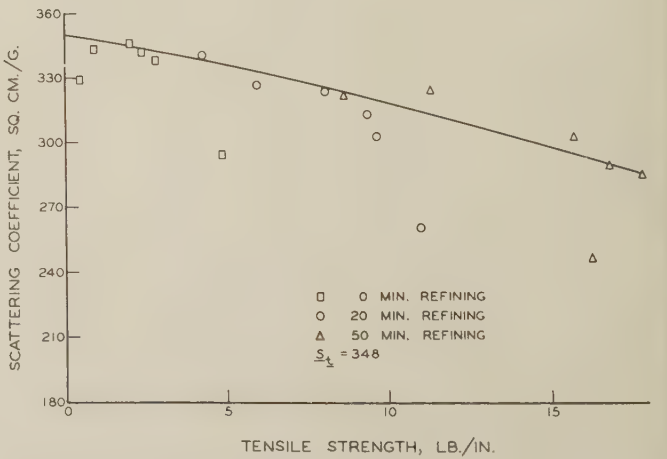

Fig. 7. Scattering coefficient versus tensile strength at 450 mμ for Coosa bleached gum

optical contact for this pulp is somewhat larger than the true bonded area.

Relation Between Bonded Area and Tensile Strength

The absolute bonded areas at various degrees of refining and wet pressing of the bleached sulphite pulp are correlated with tensile strength in Fig. 8. This curve shows that the rate of increase in tensile strength, with respect to bonded area, decreases as the bonded area increases. This would be expected, since the degree of fiber breakage increased with increasing bonded area. A closer examination of this plot, however, reveals *three* curves—one for each refining interval. This is illustrated more clearly in Fig. 8a. Similar curves were obtained for the bleached gum sulphate pulp in Fig. 9 and for the unbleached kraft pulp. The latter plot is not presented. It is evident from the relative positions of the curves that beating develops higher tensile strength per unit bonded area over the range of these experiments. They suggest that bond density (number of bonds per unit bonded area) increases with beating. Nordman and Gustafsson (*19*) have previously suggested that the entire bonded area may not contribute to the strength of paper.

Another interesting observation is that the data points for equal wet pressures in Figs. 8 and 9 fall on or near straight lines which pass through the origin. This implies that tensile strength is directly proportional to bonded area developed by beating the pulp. The data are too few to establish this relationship firmly in the present work. If the relationship is valid it may be only fortuitous because, although the tensile strength improves with beating and bonded area, beating also

Table V. Scattering Coefficients, Bonded Area, and Relative Bonded Area at Different Wavelengths

Refining interval, min.	*Wet pressing, p.s.i.*	*Scattering coefficient, sq. cm./g.*			*Bonded area, sq. cm./g.*			*Relative bonded area, %*		
		450 mμ	*550 mμ*	*650 mμ*	*450 mμ*	*550 mμ*	*650 mμ*	*450 mμ*	*550 mμ*	*650 mμ*
Weyerhaeuser Bleached Sulphite Pulp										
0	0	299	291	282	458	391	400	7.1	6.0	6.1
0	1	316	300	290	104	196	222	1.6	3.0	3.4
0	10	308	299	291	271	217	200	4.2	3.3	3.0
0	25	286	280	272	729	630	622	11.3	9.7	9.5
0	50	255	248	238	1375	1326	1378	21.3	20.4	21.1
0	150	204	199	191	2438	2391	2422	37.7	36.8	37.0
20	0	275	263	258	958	1000	933	14.8	15.4	14.3
20	1	255	246	238	1375	1370	1378	21.3	21.0	21.1
20	10	235	225	218	1792	1826	1822	27.7	28.1	27.8
20	25	218	210	202	2146	2152	2178	33.2	33.1	33.3
20	50	196	189	181	2604	2609	2644	40.3	40.1	40.4
20	150	160	152	146	3354	3413	3422	51.9	52.4	52.3
50	0	232	225	218	1854	1826	1822	28.7	28.1	27.8
50	1	209	202	195	2333	2326	2333	36.1	35.8	35.7
50	10	179	171	165	2958	3000	3000	45.7	46.1	45.8
50	25	170	164	158	3146	3152	3156	48.6	48.4	48.2
50	50	148	143	136	3604	3609	3644	55.7	55.5	55.7
50	150	119	114	109	4208	4239	4244	65.1	65.2	64.9
Bloedel Standard Unbleached Kraft Pulp										
0	1	254	303	312	138	77	50	1.7	1.0	0.6
0	50	238	262	266	690	1128	1200	8.6	14.1	15.0
0	150	253	293	298	172	333	400	2.2	4.2	5.0
20	1	222	257	261	1241	1256	1325	15.5	15.7	16.6
20	50	173	188	193	2931	3026	3025	36.6	37.7	37.8
20	150	192	204	209	2276	2615	2625	28.5	32.6	32.8
50	1	213	236	241	1552	1795	1825	19.4	22.4	22.8
50	50	173	188	192	2931	3026	3050	36.6	37.7	38.2
50	150	172	187	191	2966	3051	3075	37.1	38.1	38.5
90	50	167	182	187	3138	3179	3175	39.2	39.7	39.7
90	150	152	165	169	3655	3615	3625	45.7	45.1	45.4
Coosa Bleached Gum Sulphate Pulp										
0	0	329	329	320	433	383	390	6.0	5.3	5.3
0	1	343	342	333	114	90	92	1.6	1.2	1.2
0	10	346	343	333	46	68	92	.6	.9	1.2
0	25	342	335	326	137	248	252	1.9	3.4	3.4
0	50	338	332	321	228	315	367	3.1	4.3	5.0
0	150	294	288	279	1230	1306	1330	17.0	17.9	18.1
20	0	340	336	325	182	225	275	2.5	3.1	3.7
20	1	326	322	310	501	540	619	6.9	7.4	8.4
20	10	323	319	304	570	608	757	7.8	8.3	10.3
20	25	312	309	296	820	833	940	11.3	11.4	12.8
20	50	302	295	283	1048	1149	1238	14.5	15.8	16.8
20	150	260	255	243	2005	2050	2156	27.7	28.1	29.3
50	0	321	317	306	615	653	711	8.5	7.7	9.7
50	1	323	319	307	570	608	688	7.8	8.3	9.4
50	10	302	297	283	1048	1104	1238	14.5	15.1	16.8
50	25	288	282	270	1367	1441	1537	18.9	19.8	20.9
50	50	284	276	265	1458	1577	1651	20.1	21.6	22.5
50	150	246	239	229	2324	2410	2477	32.1	33.0	33.7
180	50	191	187	179	3576	3581	3624	49.4	49.1	49.3
180	150	163	159	151	4214	4212	4266	58.2	57.8	58.0

decreases the fiber length and fiber strength which reduce the tensile strength. On the other hand, it is possible that bonded area is the major controlling factor influencing tensile strength for these particular classified pulps over the particular beating range covered. At greater degrees of beating and with unclassified pulp the relationship may break down.

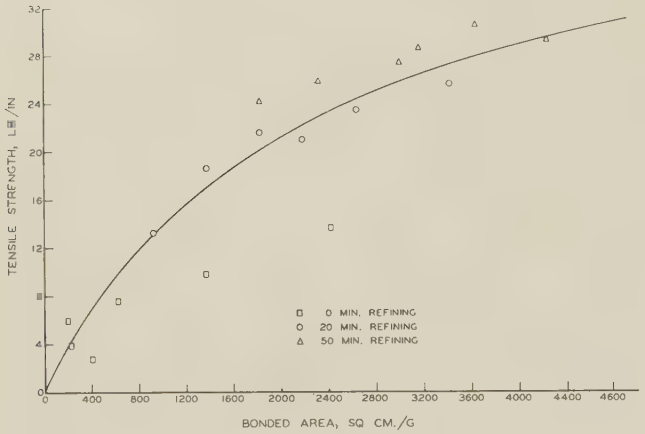

Fig. 8. Tensile strength versus bonded area for Weyerhaeuser bleached sulphite pulp

Further work will be necessary to clarify these observations. It is interesting to note, however, that Nordman and Gustafsson (*19*) found tensile strength to be directly proportional to *relative* bonded area for a variety of pulps within certain limits of beating degree and wet pressing.

Precautions Regarding the Extrapolation for s_t

In view of the scatter of the data points in Figs. 5

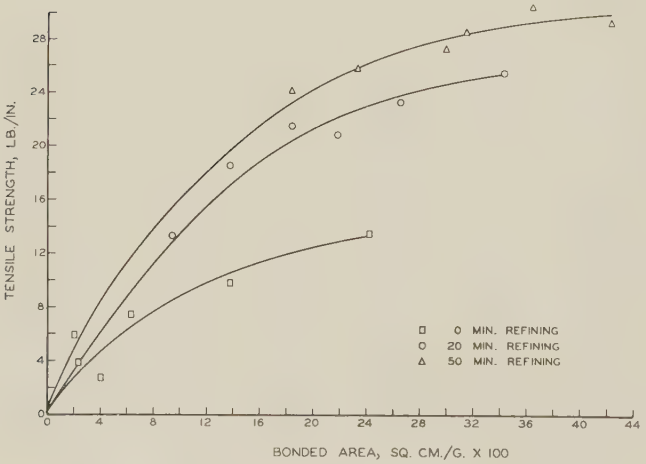

Fig. 8a. Tensile strength versus bonded area for Weyerhaeuser bleached sulphite pulp

through 7, the drawing of the curves and extrapolation to zero tensile strength to obtain s_t is done with some apprehension. If the zero minute beating interval is discarded, the remaining points are quite satisfactory for this purpose. However, it is observed that the data points seem to form separate curves for each refining interval rather than a single common curve. This is more evident for the bleached gum and unbleached kraft pulps than for the bleached sulphite. Ingmanson and Thode had noticed a possible exception to their common curve when they plotted data for the 200 and 250-min. intervals of refining time for *unclassified* pulp. These data showed a high increase in tensile strength with relatively little difference in

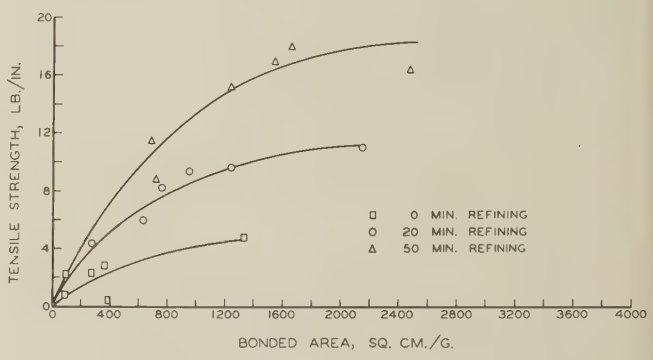

Fig. 9. Tensile strength versus bonded area for Coosa bleached gum sulphate pulp

scattering coefficient which was inconsistent with all their other data. They attributed this to possible changes in sheet formation caused by the much slower drainage of these pulps during sheet preparation. This is one of the reasons that the pulps of the present work were classified to remove the fines.

Nordman and Gustafsson (*19*) also noted separate curves for the scattering coefficient-tensile strength relationship for a variety of pulps beaten in the Valley beater. These investigators called attention to the similar slopes of the separate curves obtained over the intermediate ranges of beating. Their data points for unbeaten and lightly beaten pulps and for very low wet pressing of the sheets, however, did not form straight lines of similar slope. In some instances the scattering coefficient *increased* with greater wet pressing and tensile strength, thereby indicating a development of greater fiber surface area. Similar observations were made in the present work. Nordman and Gustafsson suggest that these effects may be caused by a dependence of the scattering coefficient on the thickness of the paper sample. Possibly, extremely high wet pressures also complicate the relationship.

It is somewhat peculiar, however, that this tensile strength-scattering coefficient relationship becomes poorer with those pulps which contain less hemicellulose and which develop tensile strength less readily with beating. Ingmanson and Thode's extrapolation method is based on the premise that the fibrillar structure which is developed on beating collapses upon fibers and fibrils during drying from water. The total dry surface area, that is, bonded plus unbonded area was believed to remain constant over the normal beating range. Perhaps for the more purified pulps the entire fibrillar structure does not completely collapse and readhere to the fiber surface during drying of the fiber. There are indications of this in the separate curves of Fig. 7

for the bleached gum sulphate pulp particularly at the shorter refining intervals. There are actual increases in scattering coefficient with increase in tensile strength at low wet pressures. This trend continues to a maximum and then the scattering coefficient falls rapidly with increasing tensile strength. If each of the separate curves were extrapolated to zero tensile without reference to the points to the left of the maximum, different s_t values would be obtained in many instances. If this effect is caused by a rigidity of the fibrillar structure which in turn is caused by a deficiency of plasticizing hemicelluloses and/or fiber fines, then it would be expected that a high alpha pulp, or better still a cotton linters pulp, might show this effect to an extreme degree.

Table VI. Physical Properties of Cotton Linters Pulp Handsheets (Beaten, Valley Beater)

S.-R. freeness, ml.	s_t cm.²/g. at 650 mμ	Opacity, %	B.E.T. surface area, sq. m./g.	Tensile strength, lb./in.	
				Instron	Zero span
		Fines Not Removed			
875	268	70.5	0.785	5.6	37.4
605	310	75.0	1.064	15.8	37.0
360	297	77.0	1.193	19.5	37.0
		Fines Removed			
870	269	69.5	0.847	6.8	39.9
590	304	73.5	1.049	11.7	42.2
360	325	75.5	1.134	16.2	42.2

Recently, a great increase in the precision of the gas adsorption technique has been attained by using krypton as the adsorbate and a thermistor unit for measuring pressure differences. This method now permits determination of surface area with a precision of 1% on a specimen of paper weighing about 0.2 g. This technique has been used to determine the surface area of sheets prepared from unbeaten and extensively beaten cotton linters pulp both before and after classification (removal of fines). Specific scattering coefficients, opacities, and tensile strength measurements were determined and the data are presented in Table VI. Examining first the data for the pulp whose fines had been removed, it is observed that *both* the scattering coefficient and the B.E.T. surface area increased over the entire range of beating. This occurred in spite of the fact that considerable bonded area must have developed as indicated by the increase in the tensile strength from 6.8 to 16.2 lb. per in. This increase in B.E.T. surface area can only mean that the fibrillar structure developed by beating did not completely collapse upon drying and that beating developed noncollapsible surface area faster than it was used in developing bonded area. This is the reason for the increase in opacity with degree of beating. It is obvious from the trend in the data of Table VI that a meaningful s_t value could not be obtained by the extrapolation procedure.

It is interesting to note that the scattering coefficient varies linearly with surface area for the classified pulp (see Fig. 10). However, the points fall in a reverse order as compared with those of wood pulps, that is, the points for the less beaten pulps are closer to the origin. The points for the unclassified pulp fall on the same line approximately, with the exception of the point for the most highly beaten pulp. This point quite clearly does not belong with the others. This is evident also from the fact that the scattering coefficients for the unclassified pulp apparently pass through a maximum even though the B.E.T. area continues to increase over the entire beating range. It is believed that the fines in this most highly beaten pulp have closed a part of the fibrillar structure which formerly scattered light, but this collapse has not yet

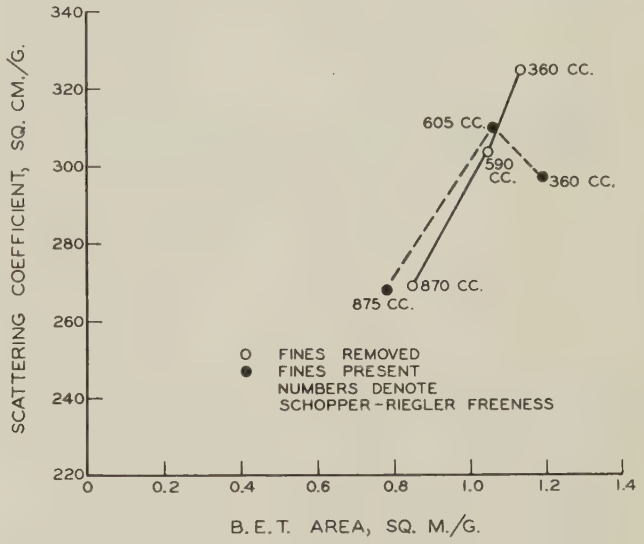

Fig. 10. Specific scattering coefficient versus B.E.T. area at 650 mμ for cotton linters pulp

decreased significantly the surface area which is available for adsorption of krypton atoms.

Highly bleached or purified wood pulps also are believed to contain noncollapsible fibrils over the early and intermediate ranges of beating. With such pulps the extrapolation for obtaining s_t is difficult and of doubtful validity.

CONCLUSIONS

The validity of the linear correlation between specific scattering coefficient and nitrogen adsorption area has been demonstrated for several papermaking pulps. The proportionality constant relating the two properties has been found to be different for different pulps but the values approach a single value of 0.044 at longer wavelengths of light. By appropriate treatment of the light-scattering and nitrogen-adsorption surface-area data, it has been demonstrated that it is possible to isolate the relationship between the bonded area in a sheet of paper and the tensile strength of the paper. There are indications, however, that beating of the pulp changes the bond density within the bonded area between fibers.

Evidence is presented which shows that the fibrillar structure of purified pulps may not collapse completely upon the fibers and fibrils during drying and in these instances the extrapolation procedure of Ingmanson and Thode (*13*) for obtaining the necessary scattering coefficient for totally unbonded fibers is difficult and in some cases of doubtful validity.

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Strength and Resilience of Polymer-Impregnated Paper Comparison of Saturants

P. J. McLAUGHLIN

The contributions of various glassy (acrylic ester, vinyl ester) and elastomeric (natural rubber, butadiene-acrylonitrile, butadiene-styrene) saturants to the mechanical properties of paper were compared by study of the load-elongation curves (Instron). The initial modulus is reduced below that of the unsaturated paper by all of the usual soft saturants. When the shear modulus of the saturant exceeds about 2000 kg. per sq. cm. the initial slope of the load-elongation curve rises above that of the base paper. All but the softest polymers raise the post-yield modulus, apparently by facilitating the strengthening of the loose interfiber bond structure during deformation. Work recovery during cycling from 30 or 60% of failing stress was used as a measure of resilience. The fiber network appears to be the principal contributor to this property; the softer saturants lower resilience. Some improvement is observed when adhesion to fiber is reduced by removal of functional groups or by reduction of molecular weight. Admixture of a water-soluble polymer [poly(N-vinyl-pyrrolidinone)] increases strength, post-yield modulus, and resilience.

Polymer dispersions used in the treatment of paper by impregnation differ as a class from natural and synthetic water-soluble additives in that the bonds introduced by means of these dispersions are generally more extensible and flexible. Polymers sufficiently polar to be water soluble are usually, for that reason, hard solids, and these are employed where needed to supplement or replace the essentially brittle bonds generated when cellulose fibers are refined. Although this distinction is generally true, a wide range of hardness, polarity, and elastomeric character is included within the class of polymer dispersions (emulsion polymers).

One purpose of this paper is to describe the range of properties attainable by saturation with dispersions of polymers, indicating the limitation on this process imposed by the necessity for coalescence of the polymer particles. Another object is to throw some light on the nature of bonding in polymer-saturated paper by examination of the load-elongation curve and by comparison of papers prepared by beater-addition with those prepared by saturation.

A detailed study of polymer variables as they affect some saturated paper properties (wet and dry tensile strengths, edge-tear strength, and solvent resistance) has been reported by Sweeney (*1*), who worked with polymers and copolymers of the acrylate and methacrylate esters. The present work deals with similar polymers, as well as with those based on monomers of other compositions. A variety of polymeric saturants in emulsion form have recently been investigated by Thommen and Stannett (*2*) who explained some of their results in terms of polymer adhesion to cellulose and the effect of emulsifying agent. Papers saturated with some of the same polymer types are described below.

DISCUSSION OF RESULTS

A single typical saturating base paper was used in a considerable part of the work; this paper is described in detail in the Experimental Section. Cross-machine direction tests were carried out in all cases so as to emphasize the role of the saturant.

Characterization of Polymers Used as Saturants

Films of each of the polymers were prepared and shear modulus was measured as a function of temperature over the range −70°C. to +70°C. (*3*). Some of the data from the resulting curves are given in Table I. The temperature at which the shear modulus equals 300 kg. per sq. cm. (T_i as defined by Williamson (*4*)) approximates the inflection point on the curve and is an approximate measure of the polymer hardness. However, the shapes of the curves above T_i vary considerably so that it appeared useful to record also the value of the shear modulus G at 20°C., close to the temperature at which paper strength was measured, 23°C.

Effect of Polymer Properties on Load-Elongation Curve of Saturated Paper Initial Modulus. The effect of a number of polymers at the 46% level of incorporation

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Table I. Mechanical Properties of Saturated Papers—Comparison of Saturants

Designation	Polymer[a] Monomer composition[b]	T_i[c] °C.	Shear modulus, 20°C. kg./cm.²	Functional group	Modulus,[d] p.s.i. × 10^{-3} Initial	Post-yield	Tensile[d] strength factor	Elongation,[d] %	Toughness[e] in.-lb.
A	Isoprene cis	−64	4.9	None	57	13	18	10.3	1.27
B	Butadiene 66 Acrylonitrile 34	−25	5.8	None	54	10	14	9.6	0.97
C	Butadiene 66 Acrylonitrile 34	−23	12.0	None	48	11	14	9.4	0.96
D	Butadiene 54 Styrene 46	−19	3.2	None	72	18	27	10.7	2.03
E	Ethyl acrylate	−16	1.4	None	55	8	10	7.7	0.71
F	Ethyl acrylate	−13	3.6	COOH	59	14	21	11.0	1.60
G	Ethyl acrylate 89 Methyl methacrylate 11	− 7	4.0	COOH	67	17	26	13.4	2.39
H	Vinyl propionate	+ 3	33	None	84	14	22	9.0	1.35
J	Methyl acrylate	+13	23	COOH	87	22	34	12.5	2.70
K	Methyl acrylate 90 Ethyl acrylate 10	+17	100	None	69	18	28	13.2	2.43
L	Methyl acrylate	+25	1150	None	77	20	31	13.3	2.69
M	Vinyl acetate	+26	2400	None	149	25	39	7.7	2.55
N	Ethyl acrylate 45 Methyl methacrylate 55	+39	2650	None	140	21	39	9.9	2.78
O	Ethyl acrylate 55 Methyl methacrylate 45	+43	8400	$CONH_2$	205	23	39	8.3	2.41
P	Methyl methacrylate 90 Ethyl acrylate 10	[f]	..	COOH	64	9	9	4.4	0.33
P′	Methyl methacrylate 90 Ethyl acrylate 10	[f]	..	COOH	115	11	20	6.7	1.18
Base paper	No saturant	..	..	..	119	12	21	5.7	0.67

[a] All were applied from emulsion at 45 to 47% on fiber, except H (39%). Papers were dried at 180°F., (82°C.) 5 min.
[b] Composition of the principal monomers excluding functional comonomers, where present.
[c] Temperature at which shear modulus G of polymer film equals 300 kg./cm².
[d] Instron tester was used at 10% per min. rate of strain. All tests were made in cross-direction. Distance between jaws = 2 in. Tensile factor = tensile strength in lb./in. width divided by basis weight (lb./3000 sq. ft.), multiplied by 100. (Young's modulus)
[e] Area under load-elongation curve, measured by means of an integrator. Sample was 2 in. long; 1 in. wide.
[f] This polymer does not form a film from emulsion; T_i estimated from composition would be *ca.* 75°C. However, some strength is developed by partial sintering of the polymer particles when the saturated paper is heated (P′) at 300°F., 10 min.

is shown in Table I. It is interesting that the initial modulus of the saturated paper is reduced below that of the base paper for saturants having shear moduli G below about 2000 kg. per sq. cm. (20°C.). Figure 1 shows the shapes of the curves for base paper and for papers saturated with polymers having G (20°C.) above and below about 2000 kg. per sq. cm. This value corresponds roughly to a polymer T_i around 25°C. Figure 2 illustrates the relation of modulus (calculated from the initial slope of the curve) to polymer hardness (G, 20°C.). Data for polymer P have been omitted; the behavior of this saturant will be discussed below. This reduction of the modulus by incorporation of the softer polymers may indicate a lubrication of fibers by saturant permitting easier deformation of the sheet. It is probably related to a similar effect observed with polymer-treated textiles. Ease of drawing-out of a single severed yarn from a cotton fabric is increased when the fabric is treated with a soft polymeric (acrylic ester or other) saturant (*5, 6*).

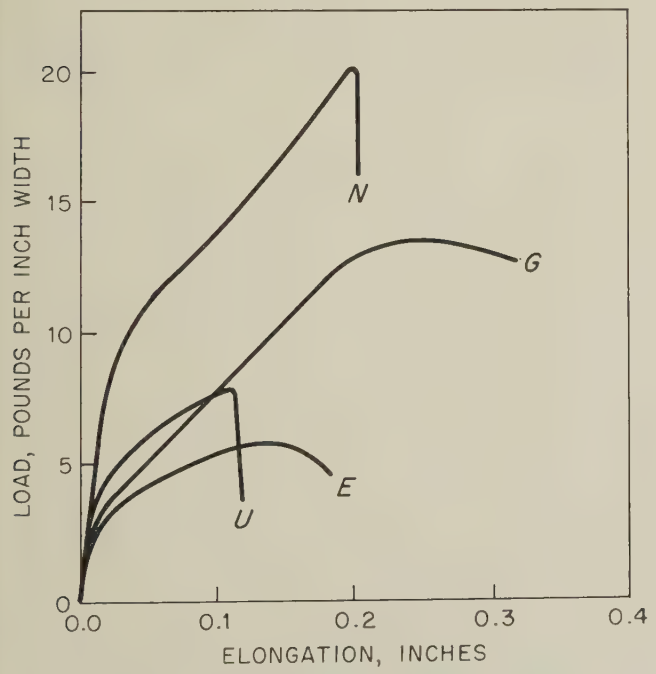

Fig. 1. Load-elongation curves for papers saturated with polymers N, G, and E (Table I) and for unsaturated paper (U)

Post-Yield Modulus.—The unsaturated paper shows a relatively well defined yield-point at about 1.1% elongation and the saturated papers show yield points

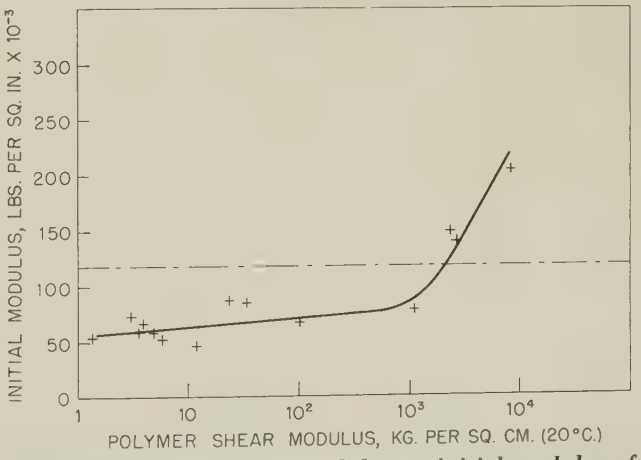

Fig. 2. Effect of polymer modulus on initial modulus of saturated paper (dashed line represents initial modulus of unsaturated paper)

at elongations close to this value. All of the curves represented by Table I including that of the base paper also show a well defined post-yield slope. It is usually assumed (*7*) that this portion of the curve for lightly beaten fibers is generated by the rearrangement of the loose interfiber bond structure and that strain-hardening occurs as this relative movement permits better bonding. The incorporation of all but the softest saturants appears to facilitate this process. Even some of the very soft saturants which depress the initial modulus tend to raise the slope of the post-yield portion (polymers D, F, G) and the effect is pronounced with the hard polymers. Figure 3 shows the relation of post-yield modulus of the saturated paper to the shear modulus of the polymer at 20°C. (data for polymer P omitted).

Tensile Strength Factor. The effect of polar functional groups on tensile strength has been illustrated by Sweeney (*1*) who studied saturations at 45% on fiber of a different base paper from that of Table I. It was shown that introduction of carboxyl increases tensile strength and reduces edge tear strength for polymers having T_i values above −30°C. However, the effect of carboxyl was shown to be less pronounced at higher T_i values (around 25°C.). The present study confirms the effect of carboxyl on tensile strength for polymers (Table I) whose T_i values are low and approximately equal (E and F). The absence of any effect of a polar group ($CONH_2$) on harder polymers of comparable T_i is illustrated by the tensile strengths of papers used on polymers N and O (Table I).

Toughness. The data on saturated paper toughness, for acrylic esters polymers used as saturants, are shown in Fig. 4. Over a considerable range of polymer hardness very little effect on toughness is noted. The constancy of this property is due in part to the differing effects of saturant hardness on tensile strength and extensibility: as one rises the other is reduced. Toughness is related to the product of these two properties.

The abrupt decrease in toughness for shear moduli about 10,000 kg. per sq. cm. represents the data for polymer P, essentially a nonfilm-former.

Effect of Heat Treatment. Table II compares the effects of heating (beyond that employed in drying the paper) on various saturated papers described also in Table I. Pronounced increases in initial modulus are brought about by heating papers containing butadiene copolymers (B and D). In the case of the butadiene-styrene saturant (D) a substantial increase in tensile strength factor is also effected. Undoubtedly cross-linking through residual unsaturation accounts for part of this change, as suggested by Thommen and Stannett (*2*).

Table II. Effect of Additional Heating on Properties of Saturated Papers

Polymer[a]			Modulus, p.s.i. × 10^{-3}[b]				Tensile[b] strength factor	
			Initial		Post-yield			
Designation	Type	T_i, °C.	Dried	Heated	Dried	Heated	Dried	Heated
B	Butadiene:acrylonitrile	−25	54	65	10	11	14	13
D	Butadiene:styrene	−19	72	116	18	21	27	35
E	Acrylic ester	−16	55	57	8	9	10	12
G	Acrylic ester (COOH)	− 7	67	58	17	19	26	27
N	Acrylic ester	+39	140	149	21	21	39	38
O	Acrylic ester ($CONH_2$)	+43	205	172	23	24	39	39

[a] See Table I for more complete description of polymers: levels of incorporation and base paper as in Table I.
[b] Same procedures as in Table I. Data for paper which has been dried only (180°F. (82°C.), 5 min.) correspond to those of Table I. Additional heating was done at 300°F. (149°C.), 10 min. (Young's modulus)

The saturants of Table II all have sufficiently low T_i values and shear moduli at application temperatures to form good films *in situ* during the drying operation. The effect of heat on papers containing soft polymers such as E, containing no functional groups, is thus not pronounced.

Papers based on functional group-containing saturants (G and O) show an appreciable reduction in initial

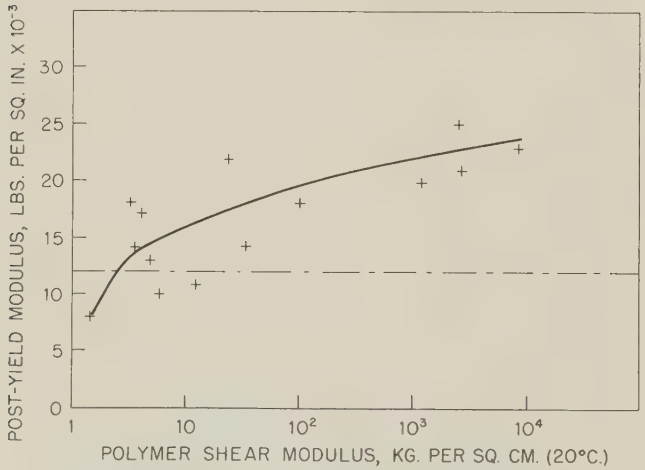

Fig. 3. Effect of polymer modulus on post-yield modulus of saturated paper (dashed line represents post-yield modulus of unsaturated paper)

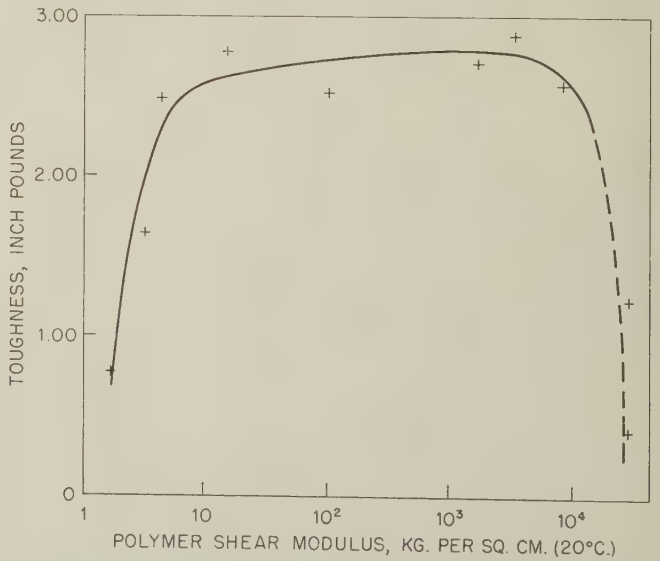

Fig. 4. Effect of polymer modulus on saturated paper toughness

modulus on heating. Although the tensile strength (Instron) is not affected, the corresponding value measured on the Scott IP-4 tester shows a considerable increase on heating, and wet tensile strength is greatly increased. These latter changes have been summarized by Sweeney (*1*). It is believed that condensation reactions involving the saturant principally account for the observed increases. However, it is not unlikely that some reaction with cellulose also occurs during heating, especially with carboxylic saturants.

Saturation with Very Hard Polymers in Emulsion Form. Data on a relatively very hard acrylic ester polymer are included in Table I and Fig. 4 to illustrate a natural limitation on the use of polymers in dispersion form as paper saturants. It is clear that in this case (polymer P) essentially no film formation by particle coalescence occurred during the drying of the saturated paper. It has been shown by Brown (*8*) that the principal agent in bringing about film formation is the extremely high capillary pressure at the air-polymer-water interface, present only during the drying operation. If the polymer modulus G is excessive, the dispersed particles do not deform adequately under this pressure. The slight development of strength with this saturant is thus not the result of poor intrinsic affinity for cellulose but rather of inadequate deformation and adaptation to the fiber surfaces.

This result parallels the experience recently reported by Thommen and Stannett (*2*) with a hard saturant of soft saturant resulted in a lowering of initial modulus and tensile strength factor. Elongation and toughness were markedly increased by saturation.

Effect of Rate of Strain Application. It is well recognized that rate of straining strongly affects the measured properties of paper. It was of interest to see how this factor altered the load-elongation curves of two papers containing hard and soft saturants (shear moduli at 20°C. of 2650 and 1.4 kg. per sq. cm. respectively).

The softer saturant (polymer E) showed an initial modulus not affected by strain rate over the range 10 to 500% per min.; post-yield slope and tensile strength were strongly increased over this range (Table IV).

The more brittle polymer N showed an increase in moduli followed by a decrease as the testing became more rapid; tensile strength rose slowly then showed no increase with further increase in rate (100 to 500% per min.). Similar behavior would be expected with polymer M (homopolymer of vinyl acetate).

Measurement of Saturated Paper Resilience. An attempt to compare the resiliences contributed to paper by various polymers was made as summarized in Table V. Work recovery was calculated as the ratio of area under the curve for de-straining to that for strain application.

By far the greatest resilience was shown by the unsaturated paper. An acrylic ester polymer E containing no functional groups showed resilience equivalent to that of a butadiene-acrylonitrile elastomer C. Introduction of carboxyl reduced the resilience perhaps by increasing the adhesion of polymer to fibers F. Another somewhat harder carboxylic polymer G also showed relatively poor work recovery. When average molecular weight $\bar{M}_v$ was reduced from about 2 million to about 170,000 (G′), resilience was considerably improved. It would be expected that reduction in $\bar{M}_v$ would reduce the adhesive forces between fiber and saturant.

Table III. Effect of Base Paper on Saturated Paper Properties[a]

Type of paper	Basis[b] weight	Polymer E % on fiber	Modulus,[c] p.s.i. × 10^{-3} Initial	Modulus,[c] p.s.i. × 10^{-3} Post-yield	Tensile[c] strength factor	Elongation, %	Toughness[d] in.-lb.
Bleached kraft	30	None	116	16	18	4.7	0.35
		49	107	14	15	6.6	0.67
Bleached kraft	50	None	139	13	18	4.5	0.63
		47	83	10	10	6.6	0.81
Unbleached kraft	112	None	31	5.4	4.8	2.6	0.24
		48	33	2.7	3.9	6.9	0.81
Unbleached kraft	176	None	24	3.8	7.4	3.5	0.48
		48	11	1.4	7.7	10.6	1.52

[a] In each case, polymer E of Table I was the saturant.
[b] Lb. per 3000 sq. ft.
[c] Instron tester at 10%/min. rate of strain: all tests were made in cross-direction. Distance between jaws = 2 in. Tensile strength factor = tensile strength in lb./in. width divided by basis weight (lb./3000 sq. ft.), multiplied by 100.
[d] Area under load-elongation curve, measured by means of an integrator.

closely related composition, polymethyl methacrylate, and with polyvinyl chloride. The present data for P′ (Table I) show that further heating of the dried paper effects a slight strength development, probably by partial sintering of the discrete polymer particles.

Use of fugitive coalescing agents (solvents) at moderate levels would permit the introduction of harder saturants; this procedure would be limited, however, by the effect of the solvents on emulsion stability and by the necessity for complete removal from the paper in order to realize the desired strength.

Effect of Base Paper. The results summarized in Table III show that the reduction in initial modulus caused by saturation with the softer saturants is not peculiar to the base paper of Table I. Four other papers of widely differing weights and strengths were saturated with polymer E of Table I, a homopolymer of ethyl acrylate. The properties of the saturated papers were strongly affected by the properties of the base papers. With one exception, however, introduction of the

Table IV. Effect of Rate of Strain on Properties of Saturated Paper

Rate[a] of strain	Polymer N (T_i = 39°C.)[b] Tensile strength factor	Modulus, p.s.i. × 10^{-3} Initial	Modulus, p.s.i. × 10^{-3} Post-yield	Polymer E (T_i = −16°C.)[b] Tensile strength factor	Modulus, p.s.i. × 10^{-3} Initial	Modulus, p.s.i. × 10^{-3} Post-yield
1	31	132	18	..	..	..
10	39	140	21	10	55	8
100	42	144	28	18	53	12
500	41	135	26	24	54	17

[a] In per cent per min. (Instron tester).
[b] See Table I for description of these saturants and procedures used.

Effect of Admixture of Water-Soluble Polymer. Another procedure effective in increasing the resilience of an acrylic ester polymer-saturated paper is shown in Table VI. Introduction of poly(N-vinyl pyrrolidinone)

Table V. Straining-Destraining Cycles: Papers Containing Various Saturants

Polymer[a] Design-ation	Type	T_i, °C.	Per cent work recovery[b] 60% failing stress Cycle 1	60% failing stress Cycle 5	30% of failing stress Cycle 1	30% of failing stress Cycle 5
..	Base paper: no saturant	..	71	95	93	100
C	Butadiene: acrylonitrile	−23	41	68	68	91
D	Butadiene: styrene	−19	19	51	..	..
E	Acrylic ester	−16	42	72	68	91
F	Acrylic ester (COOH)	−13	18	53	36	74
G	Acrylic ester (COOH)	− 7	18	49	48	75
G′	Polymer G, reduced molecular weight	− 7	31	52	70	89

[a] Saturants, level of incorporation, and base paper as in Table I.
[b] Cycling from 60 or 30% of failing stress at 10% per min. rate of strain and de-strain (Instron). All samples were tested in cross-direction. Areas under curve on each cycle were measured by integrator.

having a K-value of 64 raises the work recovery as well as the tensile strength and initial and post-yield moduli. This tough water-soluble polymer adheres well to cellulose and apparently does not interfere at moderate levels with the film formation of the dispersed polymer. There is a considerable reduction in extensibility at failure (from 13.7% for polymer G alone to 9.8% when 11% poly(N-vinyl pyrrolidinone is also present).

Table VI. Effect of Admixture of Water-Soluble Polymer

Saturant composition Polymer G[a]	Poly (NVP)	Modulus,[b] p.s.i. × 10^{-3} Initial	Post-yield	Per cent work recovery[b] Cycle 1	Cycle 5	Tensile[b] strength factor
100	0	67	17	18	49	26
89	11	112	22	21	57	31
66	34	140	26	22	61	36
50	50	136	29	30	61	38

[a] See Table I for a description of polymer G. Poly(NVP): poly(N-vinyl pyrrolidinone); K-value of 64. Saturations at 46 to 47% on fiber. Drying at 180°F. (82°C.), 5 min.
[b] Instron tester at 10% per min. rate of strain: cross-direction tests. Cycling from 60% of failing stress.

Comparison of Saturation with Beater Addition. To obtain more information on the location of the polymer in saturated paper a direct comparison was made of beater-addition and saturation using identical fibers, those of the base paper described in Table I, and identical saturants. After de-fibering, the fibers were formed into handsheets for saturation with polymer L (T_i + 25°C.) and the same fiber slurry was used for deposition of this polymer. The results are given in Table VII.

As with saturation of the original paper, initial slope of the load-elongation curve was depressed below that of the untreated paper for both processes, although the reduction was less pronounced with beater addition.

The post-yield slope was not raised by beater addition; it was nearly doubled by saturation. This strongly suggests that the interfiber bond structure is indeed involved in the strain-hardening process with saturated papers and that this process is assisted by the added polymer as suggested above. In beater addition, the fiber-fiber bonds are interrupted by deposited polymer so that less bonds of this type are available for re-orientation and strengthening during deformation.

Table VII. Comparison of Saturation with Beater Addition Polymer L (Table I)

Method[a]	Modulus,[b] p.s.i. × 10^{-3} Initial	Post-yield	Tensile[b] strength factor	Elongation,[b] %	Toughness[b], in.-lb.
Saturation	94	41	47	8.9	2.54
Beater addition	106	23	25	7.0	1.32
Blank	129	22	20	2.8	0.32

[a] The base paper of Table I was defibered and used for beater deposition (alum) at a level of addition of 36% polymer on fiber. Water-leaf handsheets were also prepared (blank) and used for saturation with the same polymer at the same level of addition.
[b] Instron tester at 10% per min. rate of strain; procedures as used in obtaining the data of Table I.

Even though the results of Table VII show beater addition to be less satisfactory than saturation for polymer L, a polymer of similar hardness did give properties approaching the optimum by beater addition. It was shown in an earlier study (*9*) that the best combination of tensile and edge-tear strengths required a polymer having T_i around 20°C. The recent study by Sweeney (*1*) showed that the best combination of properties was realized by saturation when polymers having T_i values of about 0 to −15°C. were used (shear moduli of 2 to 10 kg. per sq. cm. at 20°C.). Where, however, reinforcement of the fiber structure to attain high tensile strength, modulus, and toughness is needed, harder polymers can be employed.

CONCLUSIONS

The results of this study strongly indicate that for papers saturated with moderate levels of polymers, the fiber-fiber bonds, largely undisturbed by saturation, play a dominant role in determining tensile strength, modulus, and resilience. The softer polymers deposited around these bonds, lower the initial modulus by permitting easier fiber-slippage. Harder saturants (shear modulus about 2000 kg. per sq. cm. at 20°C.) do not cause a reduction in initial modulus. All but the softest polymers reinforce the fiber-fiber bonds by contributing extensibility and facilitating rearrangement of the fiber network during deformation, with consequent strengthening.

The fiber network also appears to be the principal contributor to saturated paper resilience. At least with the softer saturants resilience is lowered. Some improvement is observed when adhesion to fiber is reduced by (a) removal of adhesive functional groups, or (b) reduction of molecular weight.

Behavior of saturated paper would be expected to be markedly different at higher levels of polymer incorporation (*ca.* 100% on fiber) where the concentration of fiber-fiber bonds would be greatly reduced. Greater extensibility and lower strength would be expected with the softer saturants since these rather than the fiber network would be bearing most of the load.

EXPERIMENTAL

The base paper used for the saturation studies summarized in Tables I, II, IV, V and VI was a bleached kraft paper having the following properties:

Basis weight (3000 sq. ft.)	36.8 lb.
Caliper	0.0056 in.
Apparent density	6.6

	M.D.	*C.D.*
Folding endurance (MIT)	105	30
Tensile strength (Scott IP-4) (lb. per in. width)	17.3	10.3

Other properties (cross-direction) are given in Table I. When this paper was de-fibered, the slurry was found to have a Canadian freeness of 575 cc. Following saturation with *ca.* 46% on fiber of the various saturants, the caliper was found to be close to 0.0061 in.

The nondirectional handsheets of Table VII were prepared from this base paper by de-fibering and re-formation on Noble-Wood equipment. Beater-addition was carried out by addition to the slurry of aluminum sulphate (12.5% on fiber) followed by 28% ammonia (to a pH of 7 to 8) and the polymer dispersion. Sheets were formed after 10 min. mixing. The concentration of polymer in the sheets was matched in the parallel saturation of water-leaf paper.

All of the polymer dispersions listed in Table I were either anionic or nonionic as regards emulsifier type. The work of Sweeney (*1*) showed that similar polymers dispersed with the anionic or nonionic soaps of his study gave equivalent properties.

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The Mechanism of Bonding

W. BOYD CAMPBELL

Three factors are involved in cellulose bonding—available area, contact, and hydrogen bonding. Since the use of the electron microscope and the synthesis of cellulose, it has become clear that the primary form of cellulose is elementary fibrils with about 100 molecules cross-section and about 400 sq. m. area per g. Because of internal bonding only a small part of this area is available. Consideration of various possibilities indicates that exterior surface of fibers, which varies from 1.0 to 2.3 sq. m. per g. depending on the degree of beating, is the main source of usable area. Wet pressing, which is much more intense than average pressure applied, is first factor in securing contact and is much assisted by softening due to internal fibrillation by beating. More intimate contact is brought about by liquid internal tension on drying. Final hydrogen bonding differs from crystallizing force in that there is no need for parallel orientation in the fibers to be bonded but does require close contact. Tension during drying will diminish the bonding between surfaces at right angles to the tension.

When we consider the mechanism of the bonding of cellulose fibers in the making of paper, we find that there are three fundamental factors involved. First we have to think of what surfaces are to be bonded; next, how these surfaces are to be brought together; and, finally, how they are to locked in position.

The matter of surfaces of cellulose is quite complicated because there are so many different surfaces which may be involved. To consider these it is necessary to look at the structure of fibers. As long as the botanists concerned with such structure were restricted to the use of light microscopes, they had to deduce, by a sort of circumstantial evidence, the existence of structural elements which were below the limits of resolution by light, that is, below about 0.5 μ. They had indications by polarized light and from the way fibers broke up by mechanical and chemical action. Out of such indications they deduced that the cell wall was made up of fibrils of somewhat indeterminate size, but which were more or less parallel to each other and arranged at various angles to the fiber axis at different depths in the cell wall. But there was always a feeling that possibly these fibrils were merely due to lines of fracture of the cellulose material.

Of late years, the electron microscope has greatly extended the lower limits of resolution. It is comparatively easy to see structures having dimensions of 100 A or 0.01 μ. The actual existence of elementary fibrils has been pretty well demonstrated and there is a growing feeling that they have nearly the same dimensions in all cellulose. What these dimensions are is not quite so generally agreed upon. Frey-Wyssling puts them as somewhere between 50 × 60 A. and 30 × 100 A. and having 100 molecules of cellulose in their cross section.

Still later, J. R. Colvin, of the Canadian National Research Laboratory, has been able to grow cellulose fibrils without the presence of any living material. Working on the principle that materials are elaborated in living organisms by enzyme catalysts plus suitable base compounds, he has separated the enzymes from certain bacteria, and, with these as catalyst director, glucose as raw material, and ATP as energy transformer, he has been able to grow cellulose. Not only does the cellulose grow, but it grows in fibrils of about the size found in materials of more conventional growth. Moreover, the fibrils grow, not by cellulose molecules ranging themselves side by side in a crystalline array, but by additions to the tip of the fibril. In view of all this, it seems rather certain now that cellulose, as we know it, is actually made up of such fibrils. By the use of a

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little imagination, it is possible to guess that the other carbohydrates—pentosans and hemicellulose—and probably lignin, are formed in similar manner by other enzyme catalysts and other base materials.

In growth of the wood cell, the cellulose is produced in a watery medium. At the same time, lignin and the hemicelluloses are also produced and largely fill in the spaces between the cellulose fibrils. In the wood cell, the secondary wall, which holds the main body of the cellulose, contains about 15%, by weight, of lignin. This is almost completely removed by cooking and bleaching. The noncellulose carbohydrates are removed somewhat less completely. With this removal we are left with a mass of fibrils, more or less regularly arranged, with interstices filled with water until the pulp is dried.

Calculating on the basis of 100 molecules of cellulose cross section and the dimensions by Frey-Wyssling, such fibrils have a surface area of 400 to 450 sq. m. per g. of cellulose. Purves and associates (*J. Amer. Chem. Soc.* 66: 59 (1944) found 300 to 400 sq. m. per g. in cotton cellulose which had been swollen in caustic soda and dried by solvent exchange. But cotton linters, dried directly from water, showed only 8 sq. m. per g., and ramie only 5 sq. m. per g. This was by a chemical method. Apparently, the drying abolishes a great deal of surface by bonding the fibrils together.

But this vast surface is of little direct interest to the papermaker; it is buried within the fiber and not available to make contact with other fibers. Depending somewhat on the severity of the cooking process, this lot of fairly parallel fibrils is enclosed in more or less of the primary layer. This primary layer consists of a somewhat tangled mass of fibrils which do not readily become untangled to show up as the visible fibril bundles of beaten pulp. Instead, it acts somewhat as a sort of cellophane skin enclosing the inner, more orderly, arrangement. Similar to cellophane, this skin has little ability to bond to similar skins. On swelling the inner mass, this skin may bunch up to form constrictions around the fiber. Between these constrictions, the swelling shows up under the microscope as balloon structures. Unless this layer is mostly removed by the cooking process, as it usually is in the sulphites, it must be broken up by beating before any great strength is reached.

By beating, and this includes all mechanical handling of pulp in water, the rather closely packed lot of fibrils inside the fiber are shaken apart so that the fiber swells. Further beating may cause some bundles of fibrils to break out from the mass and become visible as fibrillae. Such a process does not affect the total surface area appreciably. According to the studies of Russell and myself (*Can. J. Research*, B15: 13 (1937)) beaten pulp absorbs only about 4% more water from vapor than does unbeaten. This can be taken to indicate that it has only about 4% more total surface.

Robertson in Montreal and Ingmanson in Appleton, have measured specific surface and specific volume by the permeability method. They show the unbeaten pulp to have an external surface area of about 0.8 sq. m. per g., and a specific volume of about 1.8 cu. cm. per g., for pulp from which fines had been removed by screening. While the value for specific volume would indicate about 1.2 g. water per g. of dry cellulose, the meaning of this is not clear for it includes water in the lumen space. The surface of fibrils and fibril aggregates inside the fiber volume is not included in the 0.8 sq. m. per g.

On beating, these values increase greatly, especially in the early stages. Specific volume increases to as much as 5.5 cu. cm. per g. and specific surface to 4.0 sq. m. per g. or greater. Again the meaning of this is unclear. Specific volume, in this method, means the volume through which liquid does not flow to any appreciable extent. From the concentration of cellulose in a fiber swollen to a specific volume of 5.5, it would appear that a "consistency" of 20% counts as solid. The specific surface means the surface over which water does flow. It is not new surface necessarily, since most of it already existed as internal surface.

It is probably not even correct to think of the whole calculated 400 sq. m. surface of the elementary fibrils as actually existing. Much of this must disappear in the formation of the fibril aggregates such as are visible in beaten pulp. From the measurements of sorption versus relative vapor pressure we can, by making some simple assumptions, calculate a total surface of about 130 sq. m. per g.

Of this, the 4 sq. m. per g. external surface measured by the permeability method is only a small part, so we must infer that most of the surface is still interior. In any case, most of the external fibril aggregates and all of the interior ones will, on drying, contact and bond to their parent fibers. So, for the contact between fiber and fiber required to make paper, we must rely chiefly on the swollen condition of fibers. If the swollen volume of a fiber is x times that of the unswollen, and it crosses a similarly swollen fiber, the projected area of the crossing will be x times the area of the unswollen fiber crossing. We may expect, then, that the area available for bonding will be increased about in the proportion of the swollen volume. Both Robertson and Ingmanson have found support for this.

The next part of the problem is how to bring surfaces into contact close enough to lead to bonding. Wet pressure is the first move in this direction. If we apply a wet pressure of W p.s.i. to the sheet, the load must be carried by the areas where fibers cross each other. As these areas are much less than the total area of the sheet, the pressure per unit area of pressing must be many times W, especially as some crossings will carry no load because neighboring ones are in thicker regions. Obviously, the pressing operation has an importance other than water removal.

Next comes water removal by drying. For the removal of all water except that actually in very close contact with fiber surface, there is little effect on the paper structure. The water simply evaporates. But when this is gone, and water must evaporate from fine crevices in or between fibers or fibril bundles, another pressure effect comes into play. Evaporation of this water is accompanied by shrinkage. Cellulose itself, that is the crystal cellulose which makes up the fiber bundles, does not shrink. It is the water between these which sets up a tension drawing the cellulose surfaces together and so makes the over-all shrinkage.

To explain this, it is necessary to look at the physics of liquids, in general, and water, in particular. Even in the vapor form, where molecules are comparatively

far apart, there is an attraction of molecule to molecule which must be taken into account in precise measurements. In Van der Waals' equation, this factor takes the form of a value, a/v^2, which must be added to the pressure term, p, of the familiar "pv." When v becomes very small, as it does when the vapor becomes liquid, this term becomes very large. It is usually termed the intrinsic pressure of the liquid. Since it is difficult to conceive of any way of getting a grip on water so as to measure this tensile strength directly, it has never been so measured. But it can be calculated in several independent ways with reasonably good agreement between them. For water it amounts to 11,000 or 12,000 atm.

When water, or any liquid which wets the walls, is in a capillary tube, it is drawn upward; it is under tension. The amount of such tension can be calculated in either of two ways, (1) from surface tension and the capillary diameter, or (2) from the lowering of the vapor pressure at the exposed liquid surface when equilibrium is established. For water, this tension amounts to 142 atm. at 90% relative vapor pressure (RVP), 936 atm. at 50% RVP, and 3110 atm. at 10% RVP.

As soon as the amount of water in a cellulose fiber or a mass of cellulose, such as paper, becomes low enough to be in equilibrium with a relative vapor pressure less than 100%, this tension force comes into play to draw the solid surfaces together. That is, provided the solid surfaces are already close enough to each other so that the space between is filled with water when the humidity goes below the 100%. If the solid surfaces are free to move, or are restrained only by a force less than this tension, they will ultimately come into real contact or contact except for a molecular layer of water between them.

Since our wet pressure acted to press together surfaces lying in the plane of the sheet, the great majority of bonded surfaces in paper will also be in the plane of the sheet. There will, of course, be bonded surfaces in other planes, but these depend for their formation on chance contacts. Those which are at right angles to the sheet and parallel to the machine direction will have most strength because there is little impediment to shrinkage and consequent bonding of these. But those which are at right angles to sheet and to machine direction will be weak since the sheet tension will oppose their shrinkage and bonding. Surfaces at intermediate angles will, of course, have intermediate strength.

At the present time it in usual to refer the strength of the bonding to hydrogen bonds; that is, to regions where the hydrogen atom of a group such as OH finds itself close to an atom of oxygen or some other element with one or more pairs of unshared electrons. In such case, the positive hydrogen finds itself attracted to two different negative centers and holds them together. The energy associated with such bonds can be calculated from the data of infrared spectroscopy. It varies somewhat depending on the structure of the molecules taking part and on the closeness of the oxygen atoms being joined. Calculating from the number of probable bonds per square centimeter of crystal cellulose and an energy of 3.5×10^{-13} ergs per bond, the crystal is held together by an energy of about 500 ergs per sq. cm. Since the bonding of chance contacts must be much less than this because of lack of conformity of structure, the bonding which gives paper its strength must also be much less than this. This is made very evident by the ease with which water penetrates these bonded areas and replaces cellulose-to-cellulose bonds by cellulose-to-water bonds. Water cannot penetrate the crystal bond areas since entrance of one water molecule would require the breaking of many cellulose-to-cellulose bonds.

Probably some experiments quoted by F. P. Bowden, of Cambridge University, in *Endeavour*, January 1957, will help clarify some ideas of such bonding.

Sheets of good mica can be split, with care, so as to leave molecularly smooth surfaces. The energy of the splitting can be measured; it was found to be about 300 ergs per sq. cm. for first splitting and about 250 ergs per sq. cm. if the surfaces were brought together again and split a second time. This is not far from the energy calculated for the bonding in the cellulose crystals. But the energy per unit surface has little to do with the *force* required to separate them. This latter depends on how many bonds must be broken simultaneously. When the two mica surfaces were separated by a shear force in the plane of the surface, the force was found to be 10 kg. per sq. mm. or 1000 kg. per sq. cm. In the splitting, the force was very small because only a comparatively few bonds were being broken at one instant. But the shear action required the breaking of several million times as many at once.

The strength of paper corresponds to the tensile shear in the case of the mica. It is probable that, even where fibers are broken, the rupture is one of shear between bonded fibrils inside the fiber. That fibers are broken is evidence that the bonding of these to neighboring fibers is stronger than whatever bonding exists in the fiber itself and which may be due to primary chemical bonds or to hydrogen bonding or both.

If this view of strength development is correct, we must look at strength in machine direction as due to the bondings in the plane of the sheet plus incidental bondings due to shrinkage which can take place across the sheet. Strength in cross direction does not have such addition since, for the most part, sheet tension does not permit of much bonding in the plane giving such strength.

It should also be pointed out that not all bondings contribute to the final breaking load. A great deal of bonded surface is broken in the earlier stages of loading while distortions take place in the course of setting up of the continuous chains of bonded units which carry the final load. This earlier breaking of bonds does not affect the load which the sheet can carry but it does affect the amount of stretch remaining available. That is, if the loading is released before the final break, the breaking load obtained on a second application will not be affected, though many bonds were broken before it was applied. But a considerable portion of the stretch used up in such early loading is lost and is not available the second time, though the total stretch of the two loadings is not affected.

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Crystalline Orientation in a Flat Sheet with Respect to the Plane of the Sheet, with Particular Reference to Paper

E. A. AALTIO and J. J. HERMANS

The orientation of crystals in a sheet can be derived from the x-ray diagram if the sheet is not perpendicular to the primary beam. A very suitable method is to make the beam parallel to the sheet. The application to native cellulose is discussed in some detail, with particular reference to paper. Suitable reflexions are the paratropic reflexions (002), (101), (10$\bar{1}$). The orientation with respect to the sheet can be expressed in terms of certain parameters; a comparison of these parameters among each other for some typical cases reveals the existence of a good correlation. Some useful quantitative relations between density distribution functions for crystallographic planes are discussed in the Appendix.

PRINCIPLE OF THE METHOD

THE x-ray diagram can in principle give information about the orientation of any crystalline material in any object. The problem to be discussed here is the orientation with respect to the plane of a film. Up to the present, this has been applied to paper, but similar methods would apply to cellophane and other polymer films, sheets of pulp, cardboard and to fabrics (woven or unwoven); in short, to any crystalline or partly crystalline material in the form of a sheet. The only requirement is that crystallographic planes can be found which give x-ray reflexions that are suitable for the evaluation. These will depend on the material studied. As will be shown below, for paper sheets the reflexions which are useful in this type of work are the paratropic reflexions (002), (101), and (10$\bar{1}$) of native cellulose.

The crystal structure of native cellulose has been established with a fair degree of certainty by several authors (*1*). Table I shows data quoted from the work of Andress. The cellulose chains extend in the direction of the crystallographic b-axis. Planes which are perpendicular to the b-axis are called "diatropic." Example: (040). Planes parallel to the b-axis are called "paratropic." Example: (002), (101), and (10$\bar{1}$).

Following Polanyi (*2*), a lattice plane is designated by its representative point on a sphere of unit radius; the tangent plane in this point gives the orientation of the lattice plane; the line connecting the center of the sphere with the representative point on its surface is perpendicular to the lattice plane (*3*).

Figure 1a is an example of the distribution of diatropic planes (d), paratropic planes (p), and (021)-planes. This refers to a sample in which all the b-axes are parallel and which has rotational symmetry around this b-axis. The representative points of the paratropic planes and those of the (021) planes, in such a sample, are distributed uniformly over the circles indicated in the figure. Figure 1b gives the density distribution of diatropic and of paratropic planes when the orientation of the b-axes shows a certain amount of scatter around the fiber axis f. Finally, Fig. 1c represents the distribution of paratropic planes obtained when either Fig. 1a or 1b is rotated around a horizontal axis in the plane of the drawing. This is the distribution in a cellulose sheet which is perpendicular to the plane of the drawing and parallel to the axis b in Fig. 1a or to the axis f in Fig. 1b. It is clear that for a sheet obtained in this way, there is (a) no preference direction in the plane of the sheet, and (b) the assumption that Fig. 1a and 1b have rotational symmetry about b and f respectively implies that the orientation of any paratropic plane in Fig. 1c will be the same as that of any other paratropic plane.

As a rule, neither of these two conditions will be fulfilled. As regards condition (a), most films have a "machine direction"; it will be shown below how this is

Table I. Values of $(4/\lambda^2)\ \sin^2\theta$ According to Andress (*1*) for Native Cellulose

Plane	$(4/\lambda^2)\ \sin^2\theta$	2θ *(degrees)*	*Reflexion*
10$\bar{1}$	0.0281	14.3	Medium
101	0.0347	16.2	Medium
021, 120	0.054	20.6	Medium
002	0.066	22.9	Strong
221, 122	0.107–0.112	29.6	Weak
040, 301, 003, 103	0.145–0.151	34.5	Medium
310, 21$\bar{2}$, 311, 230			

λ = wavelength, 2θ = scattering angle. Column 3 gives the scattering angle when λ = 1.54 A (CuKα radiation).

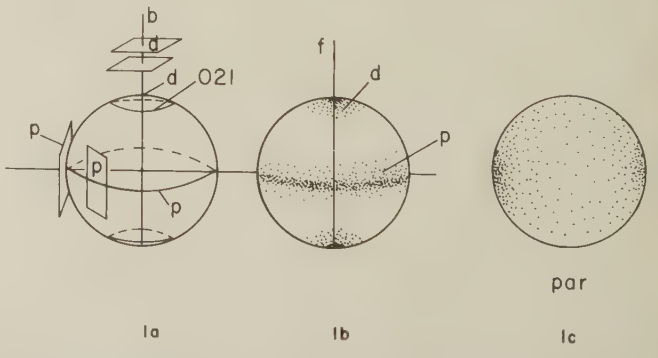

Fig. 1. Distribution of representative points, (a) when all the b*-axes are parallel, (b) when the distribution of* b*-axes shows a certain amount of scatter about the axis* f*. Rotational symmetry around* b*-axis in (a), around* f*-axis in (b). The distribution of the paratropic planes in Fig. 1c results from rotation around a horizontal axis in the plane of the drawing*

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eliminated. As regards condition (b), it is known from the work of Sisson (*4*) and of Centola (*5*) that some paratropic planes in membranes of native cellulose and in cellophane sheets have a greater tendency to lie parallel to the plane of the sheet than have other paratropic planes. It will be shown that a direct experimental proof of such a preferred orientation in paper cannot be given by the present work; indirect evidence was found by Centola (*5*), who investigated partially mercerized paper.

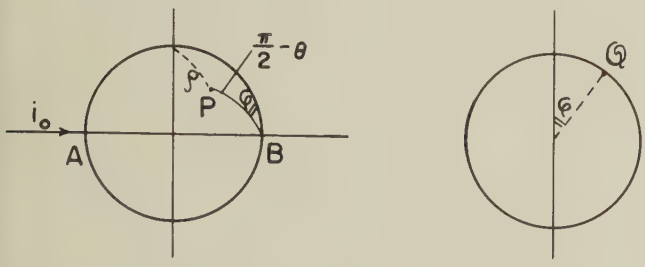

Fig. 2. Relation between the position of the representative point P and the reflexion Q in the x-ray diagram

If d is the lattice spacing, interference occurs when the angle θ between the primary beam i_0 and the lattice plane obeys Bragg's relation:

$$\sin \theta = \lambda/2d \qquad (1)$$

where λ is the wavelength. If P in Fig. 2a is the representative point of planes for which reflexion takes place, the diffraction angle is 2 θ and the diffracted beam lies in the plane APB. The reflexion in the x-ray diagram (Fig. 2b), using a flat film, will

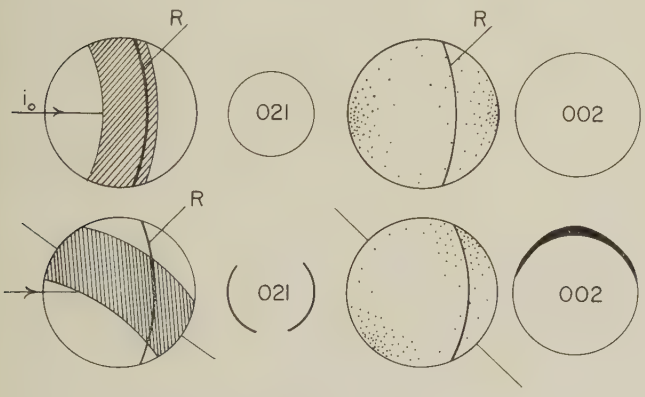

Fig. 3. Sheets perpendicular to (top row) and at an angle with the primary beam (bottom row). The resulting reflexions in the x-ray diagram are indicated

therefore be located at a point Q such that OQ = (L tan 2 θ) (L being the distance between object and film), while the angle φ in the diagram is equal to that between the plane APB and the plane of the drawing in Fig. 2a. It follows from spherical trigonometry that

$$\cos \rho = \cos \theta \cdot \cos \varphi \qquad (2)$$

Finally, it is clear that all the crystallographic planes for which the representative points lie on the circle R through P (the plane of the circle being perpendicular to i_0) will give rise to interference. This circle R is called the reflexion circle (*2, 3*).

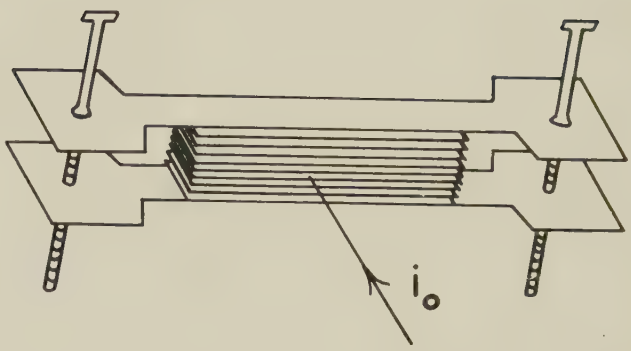

Fig. 4. Frame in which stack of sheets is mounted

This suffices to construct the x-ray diagram when the distribution of the crystallographic planes is known. All one has to do is to look for representative points which lie on the reflexion circle R.

Figure 3 applies to a sheet in which there is no machine direction or the effect of the machine direction has been eliminated. The sheet is perpendicular to the plane of the drawing. It is clear that circles of uniform density will be obtained in the x-ray diagram when the primary beam is perpendicular to the sheet (Fig. 3, top row), but that arcs or circles of nonuniform densities will be found when the sheet is tilted with respect to the primary beam (Fig. 3, bottom row). Quantitative relations will be discussed in the Appendix.

TECHNIQUE

It is only for angles less than 30° between the incident beam and the paper sheet that strong orientation effects are observed in the paratropic rings. However, when this angle is small, the diffracted beams resulting from some lattice planes are on one side of the sheet, whereas those of other planes are on the other side. These two types of reflexions will then be separated by a "shadow" of the sheet, because light scattered in a direction that coincides with the sheet will be strongly absorbed.

For this reason, the paper sheet was held parallel to the incident beam. To this end a stack of sheets was mounted in a metal frame with a thickness of 1 mm. and an (adjustable) width of about 5 mm. (see Fig. 4). The paper was then cut down to the thickness of the frame (1 mm.), so that the x-ray beam traverses a distance of 1 mm. in the object.

A possible effect of the machine direction is eliminated by using a stack of sheets in which machine and cross directions are alternating. The x-ray diagram obtained on a flat film was shown in a preliminary communication (*6*) in which the indexing was done in accordance with Andress' results (see Table I). The (021), (120) reflexions are too weak and too close to the strong (002) reflexion to be useful. The diatropic (040) reflexion is not suitable, because it occurs at approximately the same scattering angle as several other reflexions. To derive the density distribution for the paratropic planes from the x-ray diagram, the density F as a function of scattering angle 2 θ is measured with a photometer for various angles φ (see Fig. 5). It is assumed that the background due to amorphous material and temperature fluctuations is given

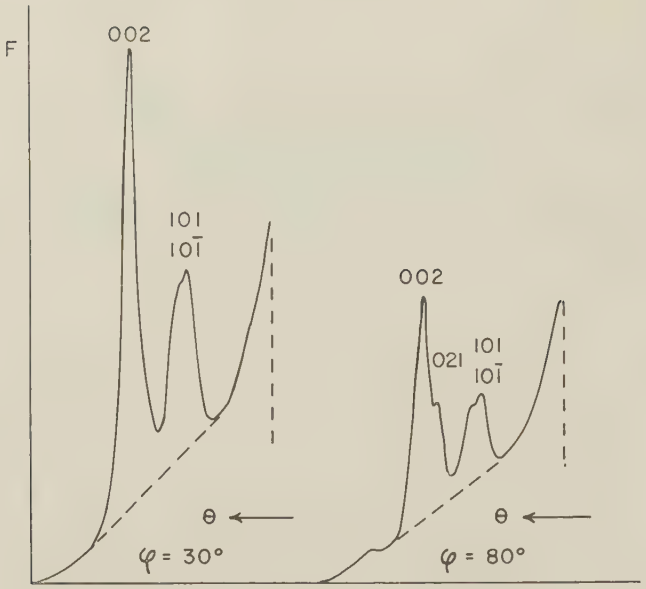

Fig. 5. Intensity **F** *for a paratropic plane as a function of scattering angle 2θ for two values of the angle φ*

with sufficient accuracy by the dotted line. The height of the peak above this line is plotted vs. φ in Fig. 6 (full-drawn curves). This figure shows results for an ordinary flat paper, a crepe paper and a "compressed" paper. The bottom figure refers to a sheet made by slightly pressing a mass of wet fibers.

When using a Geiger counter, this is set in a position where it registers the maximum of either the (002) or the (101, 10$\bar{1}$) peak. The frame holding the stack of paper is then rotated around the primary x-ray beam, keeping the Geiger counter in a fixed position. To compare the Geiger counter results (dotted curves in Fig. 6) with those found with the photometer (full—drawn curves in Fig. 6), they are reduced to the same height at the maximum of the curve.

Considering that in the photometer curves the background is subtracted from the peak heights, whereas the Geiger readings give the total intensity, the agreement between the results of the two methods is surprisingly good. This is of practical importance, because the evaluation of the photometer curves is very time consuming.

The failure of the method to give information about a possible preferred orientation of one paratropic plane compared with other paratropic planes (so-called "higher orientation") is due to the fact that the (002), (101) and (10$\bar{1}$) are the only reflexions suitable for this type of measurement and that it is practically impossible to separate (101) from (10$\bar{1}$). The (002) plane is nearly the bisector of (101) and (10$\bar{1}$) and it is therefore obvious that the orientation from (002) will be very close to that derived from the average of (101) and (101) unless the intensities of the (101) and (10$\bar{1}$) reflexions are very different from each other. In all the papers investigated, the orientation derived from the density distribution in the (002) circle was the same within experimental error as that derived from (101, 10$\bar{1}$), but this does not prove the absence of higher orientation.

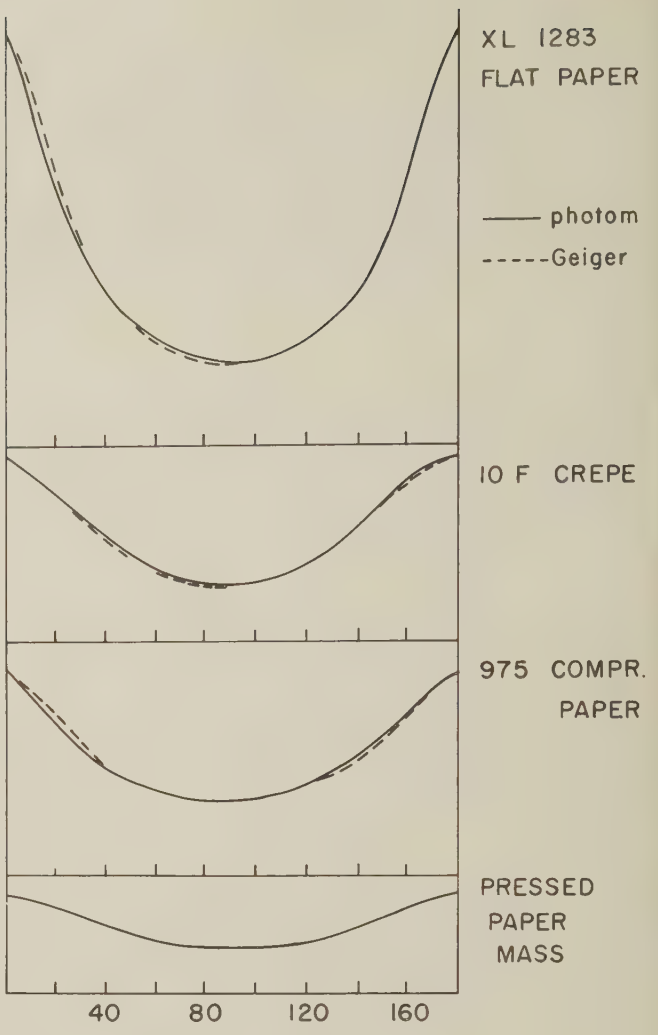

Fig. 6. Intensity **F** *as a function of the angle φ along the semicircle of a paratropic reflexion. Drawn curves found by photometry of x-ray film, dotted curves found directly with Geiger counter*

EVALUATION

For *qualitative* evaluation, a direct comparison of the curves of F (intensity) versus φ may be sufficient. Obvious parameters which may be useful for a semi-quantitative characterization are:

(a) The half-width of the maximum. This is the length of the horizontal line spanning the curve of F vs. φ at the height $^1/_2(F_{min.}+F_{max.})$. This length is best expressed in units of the angle φ.

(b) The ratio between $F_{max.}$ and $F_{min.}$. It is likely that for any given type of material there will be a fairly good correlation between these different parameters.

For a *quantitative* evaluation of the paratropic circle, the $F - \varphi$ relation is first converted to the $F - \rho$ relation. This is done by plotting F versus cos φ and then multiplying all cos φ values by the factor cos θ (see equation 2). The portion of the curve from cos ρ = cos θ to cos ρ = 1 must be found by extrapolation. From this curve, it is possible to derive an orientation factor f, similar to that discussed in Reference 3:

$$f = 1 - 2\,(\cos^2 \rho)_{av} \qquad (3)$$

This can be done, for example, by determining the ratio

$$(\cos^2 \rho)_{av} = \frac{\int_0^{\pi/2} d\rho \sin \rho \, F(\rho) \cos^2 \rho}{\int_0^{\pi/2} d\rho \sin \rho \, F(\rho)} \qquad (4)$$

both integrals being determined by graphical integration. The orientation factor f would be zero if all the b-axes were in the plane of the sheet (see Appendix); it is equal to $^1/_3$ when there is no orientation at all, i.e., when the b-axes are uniformly distributed in space (isotropic sample). Finally, f would be equal to 1 when all the b-axes are perpendicular to the sheet. A comparison of the three parameters mentioned so far is given in Table II, which shows that the correlation is good. The only discrepancy is that between the figures 60 and 64 in the half-width column which are in the wrong order as compared to $F_{max.}/F_{min.}$ and f, but the difference in orientation between the compressed paper and the crepe paper is small, and it is therefore doubtful whether this discrepancy is significant. Applications to various papers and correlations with other properties will be discussed in a subsequent article.

Table II. Values of the Half-Width of the Maximum, $F_{max.}/F_{min.}$ of Intensities, and the Orientation Factor f

	Half-width, φ degrees	$F_{max.}/F_{min.}$	
Flat paper XL 1283	47	2.84	0.144
Cellulose pulp sheet	53	2.51	0.190
Compressed paper 975	60	1.97	0.228
Crepe paper 10F	64	2.00	0.202
Slightly pressed fiber mass	114	1.51	0.258

A final remark may be made concerning the practical significance of the data obtained. It is important to keep in mind that (1) the orientation found is that of the crystalline material alone; (2) for sheets composed of fibers, this crystallite orientation may be used to draw conclusions about the orientation of the fibers with respect to the plane of the sheet, but this can be done only if the orientation of the crystalline material in the fiber is known. For wood cellulose fibers, for instance, this depends somewhat on the type of wood, and it will therefore be advisable, in a comparison of different cellulose sheets among each other, to use sheets made from the same pulp.

APPENDIX

Consider an arbitrary crystallographic plane and let the density distribution of the representative points be defined by a function $K(\beta, \phi)$ of the Eulerian angles β and ϕ (Fig. 7). This function determines the density $h(\psi)$ along the dotted circle, as a function of the angle ψ, because for any given value of ρ the angles β and ϕ can be considered as known functions of ψ. The relations between β, ϕ on the one hand and ρ, ψ on the other hand are:

$$\cos\beta = \sin\rho \cdot \cos\psi; \quad \sin\beta \cdot \cos\phi = \cos\rho; \quad \sin\beta \cdot \sin\phi = \sin\rho \cdot \sin\psi \qquad (5)$$

Now suppose we rotate around the z-axis. This means that the sheet coincides with the x-y-plane and that there is no "machine direction." The density s will then become a function of ρ only and will be equal to the average of the original density along the dotted circle in Fig. 7:

$$s(\rho) = (2\pi)^{-1} \int_0^{2\pi} d\psi h(\psi) = (2\pi)^{-1} \int_0^{2\pi} d\psi K(\beta, \phi) \qquad (6)$$

Suppose, in particular, that the distribution in Fig. 7 before the rotation around the z-axis had rotational symmetry with respect to the x-axis; this is the situation considered in Fig. 1 if x coincides with the b or f axis of this figure. Under these circumstances $K(\beta,\phi)$ is a function $K(\beta)$ of the angle β alone. Then, on account of equations 5, and using the obvious symmetry of $K(\beta)$, equation 6 becomes

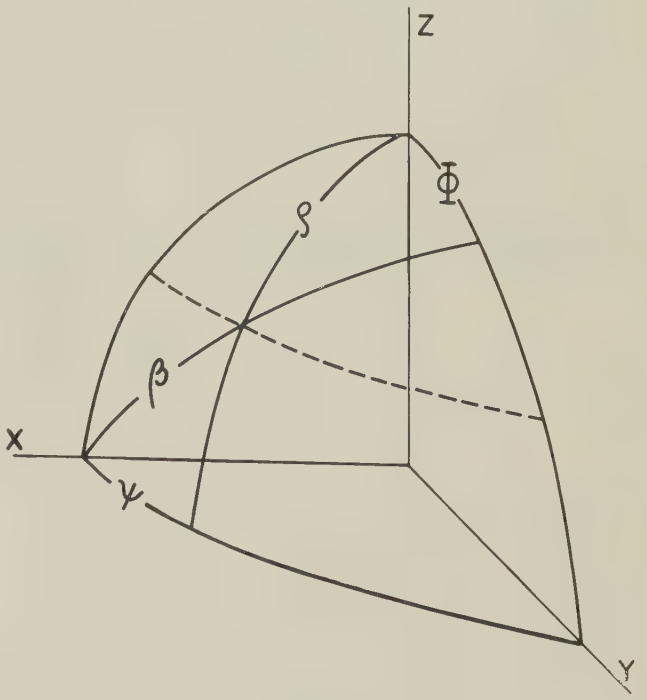

Fig. 7. Effect of rotation about an axis on the density distribution (see text)

$$s(\rho) = \frac{2}{\pi} \int_{\pi/2-\rho}^{\pi/2} \frac{d\beta \sin\beta \, K(\beta)}{\sin\rho \cdot \sin\psi} = \frac{2}{\pi} \int_{\pi/2-\rho}^{\pi/2} \frac{d\beta \sin\beta K(\beta)}{(\sin^2\rho - \cos^2\beta)^{1/2}} \qquad (7)$$

By way of example, let

$$K(\beta) = \delta(\beta - \beta_0)$$

where δ represents a δ-function. This corresponds to the situation of Fig. 1a. One finds

$s(\rho) = (2/\pi)(\sin^2\rho - \cos^2\beta_0)^{-1/2}$ when $\sin\rho > \cos\beta_0$
$s(\rho) = 0$ when $\sin\rho < \cos\beta_0$

In particular, when $\beta_0 = \pi/2$,

$$s(\rho) = (2/\pi)(\sin\rho)^{-1} \qquad (8)$$

This is the distribution of paratropic planes after the rotation around the z-axis in Fig. 7 when the distribution before the rotation was that of Fig. 1a (assuming the b-axis in Fig. 1a to be the x-axis in Fig. 7); in other words, equation 8 is the distribution of paratropic planes when all the b-axes are in the plane of the sheet. It follows immediately that in this special

case, the orientation factor f defined by equation 3 is equal to zero.

The more general equation 7 may be written in a different form by introducing new variables u and p:

$$u = \cos \beta; \qquad p = \sin \rho \tag{9}$$

$$K(\beta) = g(u); \qquad s(\rho) = t(p) \tag{10}$$

which gives

$$t(p) = (2/\pi) \int_0^p du\, g(u)(p^2 - u^2)^{-1/2} \tag{11}$$

This equation has the following solution (*7*)

$$g(u) = (d/du) \int_0^u dp\, pt(p)(u^2 - p^2)^{-1/2} \tag{12}$$

which shows that in principle the function $g(u)$, i.e. $K(\beta)$, can be derived from the density distribution $s(\rho)$ found in the sheet.

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Fiber Attraction and Interfiber Bonding—The Role of Polysaccharide Additives

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The deliberate addition of polysaccharides in the wet end of papermaking processes is a practice of long standing. Various additives have been used to improve such sheet qualities as burst, tensile, fold, internal bond, pick resistance, porosity, and many others. The additives used include starches, cellulosic materials, and the natural gums locust bean, guar, karaya, etc. More recently, studies have been made on the effect of adding hemicellulosic compositions extracted from wood pulp. While this latter study does not represent a commercial papermaking practice, it adds to the sum of knowledge on the effect of polysaccharide additives in the papermaking process. Previous workers have shown that several different polysaccharides are irreversibly sorbed by papermaking fibers without arriving at an equilibrium state. It has been shown that the initial rate of sorption varies among several additives. It has also been suggested that there is a minimum molecular weight for an additive to be sorbed or retained and give increases in sheet strength. This paper reports on a study of the degree of retention of starch additives at different dosage levels and attempts to relate the degree of retention to the responses in sheet strength. The degree of retention is different for several types of cornstarch additives. Further, the gains in sheet strength do not always parallel the amount of starch retained. Starches studied included unmodified corn, crosslinked thick boiling, acid thin boiling, chlorinated oxidized, hydroxyethyl ether, and acetate ester starches. Dosage levels were 5, 10, 20, and 40 lb. per ton. The above starches were also added, at two different dosage levels, to papermaking furnish which had been contacted with guar gum for several hours before starch additions. Both the starch retentions and the strength increases were different than when the guar pre-contact was omitted. Starch retention and sheet strength increases were determined for a series of acid thin boiling and corresponding hydroxyethyl ether starches ranging from 18 to 93 fluidity. An attempt has been made to determine the relative rate of sorption of a series of additives by varying the time of contact in the sheet mold from 15 to 120 sec. Additives studied included unmodified corn, thick boiling corn, hydroxyethyl native corn, guar gum, guar gum-thick boiling combination, carboxyethyl starch, carbamyl ethyl ether starch, and a cationic beta (dialkyl amino) ethyl ether of starch. These studies confirm theories advanced by previous workers that the rate of sorption and degree of retention of polysaccharide additives depends upon the molecular weight and structure of the additive. Furthermore, it is shown that various additives do not all have the same strengthening effect even if retained at the same level. It is to be assumed that variation in efficiency is a result of differences in "fit" against the cellulose surface and looping of some of the chain segments into the water phase. Failure to "bridge" from one cellulose fibril to another gives low strength-increasing efficiencies even at high degrees of retention.

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Despite the many advances in pulping, stock preparation techniques, and papermaking practices it is frequently necessary for the papermaker to introduce additives to get the required test values in the finished sheet. The products which have been used over the longest period of time, in the greatest volume, and at the lowest cost to the papermaker have almost without exception been polysaccharides. It is disappointing to find that there is very little definitive information in the literature on how and why polysaccharide adhesives improve paper and paperboard quality.

Many reasons suggest themselves to explain the scarcity of data. The papermaker was concerned mainly with the production of salable paper and could not afford the cost of finding out why the additives he used performed as they did. The supplier, in turn, was interested in finding a product which worked well enough to be sold at a profit. This left the problem in the hands of research laboratories who had more pressing problems or who lacked adequate facilities and techniques.

As Swanson (*33*) has pointed out, in commenting upon the need for further research in beater additives,

it is necessary to have accurate information on retention of additives if one is to understand how they affect fiber bonding. One of the more challenging examples of excellent work in this area is that of Leech (*17*) who developed a technique for determining the retention of locust bean gum and who calculated the effects the retained adhesive had on bonded area, formation, and bond strengths. More recently radio-tracer tagging techniques have been applied to sorption and retention studies of various additives in the papermaking process, Most, (*19*) Russo (*27*). We may expect to see more of this type of analysis applied to the how and why of additives in papermaking. Precision and sensitivity of radio-tracer techniques make them of unsurpassed value in studies of sorption and retention at low levels of addition.

SURVEY OF THE LITERATURE OF RETENTION AND/OR EFFECTIVENESS

The small amount of information relating to fiber-bonding efficiency of polysaccharides additives as wet-end or beater adhesives is quite inadequate as far as data on retention is concerned. Seldom has any study dealt with other than amounts of materials *added* and the resulting sheet strength data on burst, tensile, fold, tear, etc. Rarely has any one laboratory reported results with differing species of polysaccharide using more than a few additives. Similarly lacking is a rigorous study of the effect of pulping techniques, fiber furnish, and stock treatment on retention and fiber bonding with any one polysaccharide additive. The work of Karna and Nordman (*14*) on locust bean gum and guar is an outstanding exception in the latter area.

From a qualitative viewpoint, any work which demonstrates the effect of a polysaccharide additive on some sheet property comes within the purport of this report, be the effect positive or negative. It will, however, be more useful to consider principally those reports which provide *quantitative* data on the effect of amounts of retained polysaccharide, and particularly those which show some relationship between chemical composition, molecular weight, molecular configuration, and measurable positive effect. It will assist in developing a theory of the action-mechanism if we can discover correlation between structure, degree of retention, and effectiveness of polysaccharide adhesives as wet-end additives. We begin to suspect that a high degree of retention is not the sole requirement for high level performance, and that many polysaccharides can be completely retained and yet be useless for increasing strength.

Campbell (*4*) has said, "All one needs to do is to have the right kind of imagination to ask Old Mother Nature the right questions." Asking the right questions takes wisdom, patience, and inspiration. Translating the answers Nature gives us takes insight, persistence, and a lot of luck. Looking back at what others have done, and basing our translations on the additional knowledge we have gained since they did it, helps us to see where we now stand.

Swanson's exhaustive survey of the literature on beater additives (*33*) brought us up to date in late 1955 on what had been used as polysaccharide adhesives at the wet-end. Some of the references he cited warrant a more critical examination in our present orientation of, "How much was retained?" and "What did it do?" Even some prior references are worthy of examination in this respect, since they show qualitatively that certain polymer configurations among the polysaccharides are more (or less!) effective than others in increasing strengths of paper than others. This is true even in those instances where no retention data are available.

In 1937 Strasser (*31*) reported on the results of a questionnaire seeking information from the paper industry on the use of starch products in the beater and as a tub size. Answers to the question of degree of absorption of starch varied from conjecture that 100% of the starch was retained to a pessimistic view that nothing was retained if less than 2% on the fiber weight were added.

Weber, Shaw, and O'Leary (*36*) using 2% of various starches as beater sizes on clay-filled book papers found that the retention of the starches in the range of 0.23 to 1.41% (4.6 to 28.2 lb. per ton) gave bursting and tensile strengths well above the clay-filled, no-starch blank and only slightly below those values for the no-clay blank.

Cobb, et al. (*5*), recalculated the above data and claimed that it showed that the maximum values were obtained when 0.5% starch was retained. Since no direct determination of this was made, the figure is in considerable doubt.

Houtz (*13*) reported that adding 4% of corn, sweet potato, tapioca, or white potato starches to bleached sulphite showed differences in efficiency of improving the bursting strength in increasing order as listed above.

Swanson (*32*) studied the effect of adding locust bean gum to bleached coniferous sulphite after various degrees of beating and showed a 22 to 27% increase in burst at levels of 0.5% (10 lb. per ton) addition.

Pearl (*21*) studied the sorption of amylose or amylopectin on cotton linters and found that amylose sorption proceeds until the surrounding environment has been depleted of amylose. At 0.8% sorption of amylose the burst had risen 20% and at equal levels of amylopectin sorption a 40% increase was obtained. When 5% sorption of amylose had occurred, a 60 to 75% increase in burst strength was obtained.

Gruenhut (*11*) measured the rates of sorption of locust bean gum and guar and found the former to be more rapid. No data were provided on strengths of the gum-containing handsheets.

Thompson, Swanson, and Wise (*34*) showed that highly branched, high galactan-content arabogalactans were not effective as wet end additives. They also found that soft wood hemicelluloses, which principally contain hexosans, were more effective than hardwood hemicelluloses which contain principally pentosans (xylans, etc.). They suggested that there may be a critical minimum degree of polymerization below which retention and effectiveness is poor. A value of 40 D.P. was proposed to insure sufficient cohesive energy to bind two or more fibers together.

In his classic paper, Leech (*17*) demonstrated high levels of retention of locust bean gum on beaten coniferous bleached sulphite pulp. Retention rose from 32% of the gum added to unbeaten fibers to 88% of the added amount after 20 min. beating. By failing to decrease gum content or sheet strength after prolonged washing, it was shown that the sorption of locust bean

gum was irreversible. It was stated that "it is probable that strength increases are brought about by the formation of bonds involving the gum molecules. Such bonds would be more flexible than bonds between two cellulose molecules which are rigidly held in the crystalline structure of the fibers."

Shriver (*28*), studying the sorption of methyl and ethyl cellulose on cotton linters, bleached and unbleached kraft and sulphite pulps, reported that sorption was an irreversible, exothermic surface phenomenon with an activation energy of 8.2 Kcal. per mole; that is, in the same order as hydrogen bonding. He speculated that there was probably a parallel orientation of the sorbed molecule on the substrate surface.

Watson, Stewart, and Dadswell (*35*) soaked pine and eucalypt sulphate pulps in alkali soluble extracts of eucalypt pulp and precipitated the glycosan uronides on the pulps with an estimated 20 to 40% retention. All strength properties increased as shown in Table I.

Most (*19*) found the sorption of hemicellulose fractions to be a nonequilibrium, irreversible process using a radio-tagging technique.

Cushing (*6*) found that guar gum and starches added in combination to papermaking furnishes produced increases in strength greater than the sum of the increases when used alone. A hypothesis was advanced that guar gum forms a stabilizing complex with a linearly extended form of amylose resulting in a higher degree of retention of the starch added.

Russo (*27*) utilized a radio-tagging technique to study the sorption of locust bean gum on bleached coniferous sulphite. By means of an infinite bath environment the process of sorption of the gum was shown to depend upon rate of diffusion to the fiber surface, to be irreversible, and to be initially rapid as shown in Table II. The fact that no desorption took place after 24 hr. extraction argues for a highly crystalline organization of the sorbed gum molecules.

Recently Karna and Nordman (*14*) conducted an excellent study on the use of mannogalactan vegetable gums (locust bean and guar) in the paper industry. They chose the method of Keen and Opie (*15*) to determine retention rather than the more time-consuming method of Leech. Summarizing the results, it was found that locust bean was more effective than guar, as indicated in Table III. It was further shown that there was a greater effect on adding gums to suphite than to sulphate pulps and more effect on bleached pulps than on unbleached pulps. Increased lignin content caused a decrease in retention. Beating pulp for 22 min. gave a bursting strength which could be achieved by beating only 9 min. and adding 1% of locust bean gum. The tear was the same and drainage rate was much increased.

A more recent paper by Aaltio and Jouhikainen (*1*) showed the effect of some polysaccharide additives on the properties of paper. The effect of locust bean gum, oat hull xylan, aspen hemicellulose, and sodium alginate over a range from 0.25 to 10.0% was studied. The most marked effects were at low levels of addition. The maximum effect of locust bean gum was at about 1%. Oat hull xylan equaled this for breaking length at 4.5 to 5.0% and at 3.5 to 4.0 for bursting strength. Aspen hemicellulose gave low level results, while sodium alginate was almost without value. These results are typified by the data in the accompanying Table IV.

Table I. Effect of Alkali-Soluble Polysaccharides on Eucalypt Sulphate Pulp

Beating time, min.	*Burst factor*		*Breaking length, km.*		*Elongation, %*	
	Control	*Addition*	*Control*	*Addition*	*Control*	*Addition*
0	21	32	3.7	5.4	1.5	2.1
10	34	53	5.8	8.0	2.4	3.2
20	51	75	7.4	10.3	3.6	4.1
30	61	88	8.9	11.1	4.4	4.7

We can summarize our knowledge on retention of polysaccharide adhesives by outlining the process as follows.

1. Diffusion of adhesive to the cellulose molecular surface.
2. Probable hydrogen bonding mechanism of attachment.
3. Irreversible sorption or deposition of adhesive.
4. Continuing, nonequilibrium sorption as long as contact with medium is possible.
5. Reasonably rapid initial rates of sorption.

Table II. Effect of Specific Surface on Locust Bean Gum Sorption, Gum Concn. = 0.01%

Time, sec.	*Sorption rate, lb. gum/ton pulp*	
	Specific surface, cm.²/g.	
	29,900	*11,780*
60	13.56	8.76
120	18.43	11.66
200	...	14.44
240	23.6	...
300	...	16.76
400	...	24.68
480	27.6	...

We can summarize our ignorance of the process of retaining polysaccharides in the papermaking process as follows:

1. How is the polymer segment held to the cellulose fiber surface?
2. How frequently does the polymer chain become attached or bonded to the cellulose surface?
3. How much polysaccharide must be retained (bonded) on the fiber to provide maximum performance?
4. What must be the conformation of the monomer units within the polysaccharide for maximum retention and maximum effect? Is a mannose polymer more effective than a glucose polymer, and if so, why?

Table III. Effect of Adding 1% Gums to Bleached Sulfite Beaten Pulp

Gum type	*Changes in*		
	Breaking length, %	*Burst, %*	*Tear, %*
Locust Bean	+28	+41	−8
Guar	+15	+23	−9

EXPERIMENTAL PROCEDURES AND RESULTS

It has been suggested (*6*) that the effect of combinations of starches and natural gums should be examined under conditions where either the starch or the gum contacts the fibers before the other, rather than at the same time.

To provide some information on the retention of

Table IV. Effect of Polysaccharides on Strengths of Bleached Spruce Sulphite

Type	*Added, %*	*Burst*
None	..	22.5
Locust bean	0.25	27.6
	0.50	29.8
	1.00	32.6
Oat xylan	0.25	26.2
	0.50	28.8
	1.00	31.0
Aspen hemicellulose	0.25	23.2
	0.50	23.6
	1.00	25.0
Alginate	0.25	23.4
	0.50	23.2
	1.00	24.6

starch wet end additives and to carry out an analysis of the effect on sheet strengths the work described in the following experimental section was conducted.

Commercial and experimental starch products can be provided covering a fairly wide range of molecular weights. In addition, several different chemical substituent groupings are present in the respective individual commercial-modified or derivatized starches hydroxyethyl, acetate ester, alkylamino ethyl, carboxymethyl, etc., although it must be noted that the percentage of any substituent in a commercial starch is usually quite low; that is, in the order of 0.5 to 3.0%.

Retention of Polysaccharide Additives

All of the studies reported in this paper were done on handsheets prepared in the Noble and Wood laboratory sheet machine. Bleached sulphite pulp was beaten at 2.5% consistency in a 1-lb. Valley laboratory beater until the freeness was between 650 and 700 ml. S-R (Schopper-Riegler). The pulp was sized in the beater with 2% of rosin which was precipitated with enough papermakers alum to reduce the stock slurry pH to 5.2 to 5.5. Aliquots of the sized fiber slurry were diluted in the proportioner tank until a blank sheet weight of 2.5 g. (25 × 38—500, 40-lb. basis book) as a control sheet was obtained.

Sheets were pressed, and dried at 190°F. drier surface for 3 min. Six sheets per set were made without white water recirculation. Sheets numbered 5 and 6 in each set were used for all determinations.

Solutions of additives tested were prepared at 1% solids concentration, cooked for 20 min. at 195 to 205°F., and in some instances held hot before addition to the fiber slurry in the proportioner tank. Additions were made volumetrically to provide the indicated level of additive on a commercial moisture basis.

Dried sheets were conditioned for at least 24 hr. at 72°F. and 50% R.H. and tested under these conditions for bursting strength and tensile strength and elongation.

Retention data was calculated from the results of a starch determination based on the method of Browning, Bublitz, and Baker (*3*). This method required the construction of a calibration curve for each specific starch product and, in certain instances, special curves for blends of starches and other additives (*6*).

If all starch products being used in papermaking were to be retained to the same degree, it would be simple to explore different starch structures until one found the most effective substituent. To demonstrate that the end results are in part due to the difference in degree of retention several different types of cornstarch additives were added to handsheet furnish at levels of 5, 10, 20, and 40 lb. per ton (0.25, 0.50, 1.0, and 2.0% of the fiber furnish).

The results obtained when various thick-boiling unmodified, thick- and thin-boiling modified starches are added to papermaking pulp furnishes are listed in Table V. The data listed includes the type of starch, the level of addition, the amount of starch found in the sheet, the percentage of retention, the burst values, the tensile strength, and the percentage elongation.

In addition to starches a high-viscosity, completely hydrolyzed polyvinyl alcohol (Du Pont Elvanol 72-60) and a high-molecular weight polyethylene glycol (Union Carbide Polyox Coagulant) were tested at the same dosage level and reported in Table V. While no information is available on how much, if any, of these two additives was retained it can be seen that the burst and tensile strengths were both below the same values for the untreated blank sheet.

From the summarized data, many separate tentative conclusions can be made.

(*a*) *Starch Retained Versus Starch Added.* At all dosage levels and including one trial at a higher beating level (430 ml. S-R freeness) the effect of cross-linking to produce a thick-boiling starch in which amylose and amylopectin undoubtedly are chemically joined (*9*) is demonstrated in the highest degree of retention—approximately 60% in all cases.

Unmodified pearl cornstarch and a hydroxyethyl pearl type corn were next best-retained at levels of 45 to 50%. It is not certain if any significance resides in a somewhat higher retention efficiency for the hydroxyethyl starch at low dosage levels and a dropping off at higher dosage levels.

The next-retained starch, particularly at low levels of dosage, is a thin-boiling acetate ester which was retained as well as the unmodified or hydroxyethylated pearl starches. At higher dosage levels the degree of retention drops off rapidly until it is poorer than a 90 fluidity thin-boiling starch at 2% dosage.

A 90 fluidity thin-boiling starch was slightly less well-retained at 20% of all dosage levels. The low level of retention may be related to a more marked tendency to retrograde, although attempts were made to avoid this by keeping the starch cooks at 190 to 195°F. until addition to the proportioning box.

Lastly, a hypochlorite-oxidized starch, typical of the most severe molecular weight reduction practiced by the starch industry, showed the lowest level of retention.

In a later section of this paper a report will be made on the rate at which these and other starch products are sorbed upon papermaking fibers.

We thought it would be instructive to determine the effect of introducing a substituent on the degree of retention of starches of varying molecular weights. For this purpose, eight thin-boiling starches ranging from 20 to 90 alkali fluidity were compared with four hydroxyethyl ether starches ranging from 53 to 92 alkali fluidity. The data on retention shown in Table VI indicates that the thin-boiling and hydroxyethyl thin-boiling starches follow the same pattern of decreasing retention with decreasing molecular size.

Table V. Retention and Effect of Starches on Bleached Sulphite Handsheets[a]

Type	Starch Added, lb./ton	Starch Found, lb./ton	Retention, %	Burst, pt./100 lb.	Tensile, lb./in.	Elongation, %
None	..	..	..	73.0	15.7	1.98
Pearl	5	2.4	48	77.2	14.9	1.64
Pearl (T)[b]	5	3.0	60	76.0	15.9	2.65
HOEt (P)	5	2.6	52	76.0	15.2	2.12
90 TB	5	1.0	20	73.2	16.1	2.57
HOEt—90 TB	5	1.8	36	78.0	13.3	1.98
STAYCO M	5	0.6	12	79.2	15.7	2.45
Acetate—80 TB	5	2.6	52	81.0	17.0	2.79
PVA 72–60	5	..	..	70.0	13.6	2.17
Polyox Coagulant	5	..	..	66.0	14.8	3.08
Pearl	10	4.4	44	76.8	14.8	2.12
Pearl (T)	10	6.2	62	77.0	15.9	2.00
HOEt (P)	10	4.4	44	77.0	16.8	2.65
90 TB	10	2.2	22	75.0	15.9	2.43
HOEt—90 TB	10	1.6	16	80.2	16.8	2.68
STAYCO M	10	1.0	10	79.0	16.6	2.71
Acetate—80 TB	10	3.2	32	83.0	16.6	2.71
PVA	10	..	..	66.7	16.0	2.99
Polyox	10	..	..	66.0	14.7	2.71
Pearl	20	9.8	49	76.5	15.5	2.31
Pearl (T)	20	12.0	60	74.7	15.9	2.34
HOEt (P)	20	8.6	43	79.5	17.6	2.85
90 TB	20	3.0	15	74.7	15.1	2.06
HOEt—90 TB	20	2.2	11	84.0	17.0	2.74
STAYCO M	20	1.4	7	77.7	16.9	2.79
Acetate—80 TB	20	4.2	21	83.2	18.2	3.05
PVA	20	..	..	72.0	15.7	2.68
Polyox	20	..	..	68.0	14.4	2.51
		(At 430 ml. S-R freeness)				
None	..	..	..	84.0	19.5	2.79
Pearl	20	10.2	51	85.7	20.6	3.02
Pearl (T)	20	13.8	69	86.0	21.3	2.85
HOEt (P)	20	8.2	41	90.3	21.3	2.74
90 TB	20	3.2	16	85.3	20.3	2.91
HOEt—90 TB	20	2.4	12	85.0	18.6	2.93
STAYCO M	20	1.2	6	82.0	18.5	2.88
Acetate—80 TB	20	5.0	25	87.0	21.0	2.99
PVA	20	..	..	85.5	20.3	2.82
Pearl	40	17.6	44	80.2	15.1	2.45
Pearl (T)	40	21.8	54.5	80.0	18.0	2.79
HOEt (P)	40	13.8	34.5	82.0	17.9	2.68
90 TB	40	7.0	17.5	78.2	16.0	2.34
HOEt—90 TB	40	2.8	7.0	81.3	15.3	2.14
STAYCO M	40	1.8	4.5	79.5	15.6	2.31
Acetate 80 TB	40	6.2	15.5	85.5	18.2	2.99
PVA	40	..	..	71.5	14.4	2.43
Polyox	40	..	..	63.7	15.6	2.93

[a] Pulp freeness 670 to 700 ml. S-R, rosin sizing 2%, pH 5.0 to 5.1 40 lb. (25 × 38—500).
[b] (T) Thick-boiling, see reference (*9*). (P) Pearl-based.

In another study the papermaking fibers were first treated with guar gum, in the amounts of 0.25 or 0.50% which remained in contact with the fibers for 1 hr. or more. Starches were better retained (pearl, hydroxyethyl pearl) or more effective in raising the strength of these preparations, although retained to a lesser degree. We have been unable to interpret the significance of the fact that the retention of the substituted thin-boiling starches—hydroxyethyl and acetate ester—was reduced by the pretreatment with guar, while the retention of the thin-boiling starch was increased (Tables VII and VIII).

When pearl starch was used as a pretreatment, followed by guar in the proportioner, the amount of starch retained did not decrease but the sheet strength and elongation were appreciably higher than when guar was used first or when the starch and gum were introduced simultaneously.

(*b*) *Strength Increases Versus Starch Content of Sheets.* There have been many discussions in the literature on a suitable method of determining strength qualities of paper and paperboard.

It is recognized that the Mullen or burst test is of an equivocal nature, comprising some of the elements of tear, tensile, and fold, and yet since it is convenient and in many areas relates to one or more of the end-use properties of paper it is still widely used and thus a useful parameter for *comparison* purposes.

The tensile test, coupled with a measure of the elongation of the test strip gives a good measure of uniformity of formation, number of bonds per unit area and the *strength* and *elasticity* of those bonds.

When Mullen, tensile, or elongation are plotted against starch content of the handsheets, without regard to type of starch, a scatter-pattern results which is without clear meaning.

However, if individual starches are examined separately, it appears that some starches differ in their ability to increase strength, as is to be expected. The pearl starch retained over a range of 2.4 to 17.6 lb. per ton caused a fairly constant but small (6 to 7%) increase in Mullen. Tensile is decreased slightly, while per cent elongation rises perceptibly as the amount retained increases. The DMU crosslinked starch retained in a range of 3.0 to 21.8 lb. per ton has a similar effect.

Noticeably different is the effect of a thick-boiling

Table VI. Effect of Hydroxyethylation on Retention and Sheet Strength[a]

Type	Starch: Fluidity	Starch: Found, lb./ton	Starch: Retained, %	Burst pt./100 lb.	Tensile, lb./in.	Elongation, %
None	..	..	..	73.5	17.4	2.51
TB	20	7.2	36	82.0	17.5	2.34
TB	30	4.6	23	79.5	15.5	2.29
TB	40	4.4	22	81.5	19.6	2.85
TB	50	4.0	20	79.5	19.3	2.85
HOEt—TB[b]	54	3.8	19	77.7	18.2	2.45
TB	60	3.4	17	76.5	19.6	2.93
TB	70	3.0	15	76.6	17.6	2.54
HOEt—TB	73	3.6	18	76.2	15.8	2.00
TB	80	2.8	14	78.5	18.6	2.74
HOEt—TB	82	2.4	12	77.5	18.4	2.65
TB	90	2.4	12	79.5	18.1	2.62
HOEt—TB	91	2.8	14	75.5	17.6	2.54

[a] Starches added at 20 lb./ton (1.0%) to bleached sulphite pulp, freeness 650–700 ml. S-R, rosin sized 2.0%, pH 5.0 to 5.1.
[b] TB = Acid thin-boiling. HOEt = Hydroxyethylated thin-boiling (2.0% C_2H_4O).

hydroxyethyl ether of starch which causes a regular increase in Mullen and tensile as the amount retained rises from 2.6 to 13.8 lb. per ton.

The thin-boiling starches at 90 fluidity while retained to a much lesser degree, showed progressive increases in Mullen, tensile, and elongation over the range 1 to 7 lb. per ton. Most outstanding was the acetate ester starch in Mullen, tensile, and elongation increase at retention levels of 4 and 6 lb. per ton; this in spite of a low level of 20% retention.

Low viscosity hypochlorite-oxidized starch retained poorly at 0.6 to 1.9 lb. per ton, raised the Mullen only slightly, caused little or no change in tensile, but improved the elongation considerably.

When the eight thin-boiling starches and the four hydroxyethyl ether starches are compared it is seen that the decrease in Mullen, which seems to be a general trend related to decrease in molecular size for both thin-boiling and hydroxyethyl starches, does not correlate with tensile or elongation. At equal starch-content levels the thin-boiling starches give higher tensile and elongation than do the hydroxyethyl starches. This will be discussed in a later section.

A casual comparison of the Mullen values of sheets made with DMU crosslinked pearl, unmodified pearl and hydroxyethyl pearl seems to indicate that addition of these starches in the deckle box at extreme fiber dilutions (consistencies of 0.023%) gave higher Mullen, tensile, and elongation values than when the starches were present in the proportioner tank at higher consistencies (0.128%) and for much longer periods.

Rate of Retention of Starch Additives

The experiments described in this section were designed to obtain information on the relative rates of sorption of various starch wet end additives on bleached sulphite fibers which had already been beaten to the desired freeness and sized with rosin set with alum at pH 5.0 to 5.1.

By addition of the cooked starch adhesives to the deckle box of the Noble & Wood laboratory sheet machine, mixing and forming the sheet after set time intervals it was hoped that information on the relative rate of sorption of various starches could be gained. To this end several different starch modifications were cooked at 1% solids concentration, mixed with paper fiber slurries and sheets formed after 15-, 20-, 30-, 60- and 120-sec. contact.

Starches used in this portion of the study were unmodified pearl, crosslinked thick-boiling pearl, hydroxyethyl, dialkyl aminoethyl ether, carboxyethyl, and carbamyl ethyl pearl starch and, in addition, a starch-guar combination, and guar alone. The results of this study showing starch type, time of contact, amount of starch found, percentage retention of starch, Mullen, tensile, and elongation are listed in Table IX.

The most effective retention of starch was from a starch-guar combination giving retentions of about 50%.

The next best-retained starch was a thick-boiling DMU-cross-linked (*9*) product, giving 35 to 40% retention.

Next in rank were unmodified pearl starch and a carbamyl ethyl ether starch at 25 to 30% retained.

A carboxyethyl ether starch (anionic) was next at 15 to 20% retention, followed in last position by a hy-

Table VII. Effect of Pretreatment of Bleached Sulphite Pulp with Guar Gum on Retention and Strengths When Starches Are Added.[a]

Starch type	Starch: Found lb./ton	Starch: Retained %	Burst pt./100 lb.	Tensile, lb./in.	Elongation, %
None	..	...	83.5	16.8	2.23
Pearl	3.6	72 (48)[d]	84.7	19.0	2.74
Pearl (T)	2.6	52 (60)	80.7	18.9	2.54
HOEt (P)[b]	4.0	80 (52)	85.2	19.5	2.88
90 TB	2.0	40 (20)	83.5	17.8	2.14
HOEt—90TB	1.2	24 (36)	80.2	19.4	2.65
STAYCO M	0.8	16 (12)	83.2	16.4	2.05
Acetate—80 TB[c]	2.0	40 (52)	83.6	18.4	2.40

[a] Guar added at 5 lb./ton after beating; freeness 650–700 ml. S-R, rosin sized 2%, pH 5.0 to 5.1 starches added at 5 lb./ton.
[b] Hydroxyethyl ether content = 2.0%.
[c] Acetyl content = 2.0 to 2.2%.
[d] Percentages retained at this dosage level if guar pretreatment is omitted.

Table VIII. Effect of Pretreatment of Bleached Sulphite Pulp with Guar Gum on Retention and Strengths When Starches Are Added[a]

Starch type	Starch: Found, lb./ton	Starch: Retained, %	Burst pt./100 lb.	Tensile, lb./in.	Elongation, %
None	..	...	84.2	20.1	2.68
Pearl	5.2	52 (44)[d]	86.7	18.6	2.34
Pearl (T)	4.6	46 (62)	87.2	18.9	2.31
HOEt (P)[b]	5.0	50 (44)	89.2	17.9	2.23
90 TB	2.2	22 (22)	85.2	17.2	1.99
HOEt—90TB[b]	1.4	14 (16)	84.2	21.5	3.08
STAYCO M	0.8	8 (10)	88.5	20.5	2.85
Acetate 80 TB[c]	1.0	10 (32)	84.2	18.6	2.26
Pearl (10 lb./ton-beater)	5.4	54	81.7	16.9	2.65
Pearl + 10 lb./ton guar	5.6	56	87.8	18.4	3.24

[a] Guar added at 10 lb./ton after beating; starches added at 10 lb./ton.
[b] Hydroxyethyl content = 2.0% (D. S. = 0.072).
[c] Acetyl content = 2.0 to 2.2%.
[d] Percentages retained at this dosage level if guar pretreatment is omitted.

Table IX. Effect of Time of Contact on Retention of Polysaccharide Additives[a]

Starch type	Contact time, sec.	Lb./ton found	Retention starch, %	Burst pt./100 lb.	Tensile, lb./in.	Elongation, %
None	15	..	..	77.0	16.1	2.31
Pearl	15	4.6	23	84.0	17.4	2.79
Pearl (T)	15	8.2	41	79.0	17.2	2.60
HOEt (P) nonionic[b]	15	2.2	11	83.0	18.9	3.19
CES (P) (anionic)[c]	15	3.4	17	85.2	18.2	2.60
Cationic (P)[d]	15	2.0	10	75.0	17.3	2.68
Carbamyl (P)[e]	15	7.2	36	81.0	18.3	2.79
Guar-Starch[f]	15	6.0	60	76.0	15.0	3.05
Guar	15	..	..	77.2	16.8	2.45
Pearl	20	5.0	25	81.0	15.2	2.79
Pearl (T)	20	7.6	38	77.2	17.3	3.08
HOEt (P)	20	2.2	11	81.7	19.0	3.13
CES	20	3.2	16	81.2	17.9	3.05
Cationic	20	2.2	11	73.7	17.2	2.93
Carbamyl	20	5.4	27	76.0	17.9	2.93
Guar-Starch	20	6.2	62	73.2	16.0	2.45
Guar	20	..	..	74.0	16.1	2.40
Pearl	30	5.4	27	81.2	16.2	3.02
Pearl (T)	30	7.0	35	77.2	18.8	3.22
HOEt (P)	30	1.2	6	78.5	18.6	2.91
CES	30	3.4	17	86.0	17.8	3.33
Cationic	30	2.2	11	75.5	15.2	2.93
Carbamyl	30	5.4	27	79.5	18.6	2.93
Guar-Starch[a]	30	5.6	56	78.5	17.4	2.68
Guar	30	..	..	83.0	18.6	2.88
Pearl	60	5.6	28	80.2	17.6	2.68
Pearl (T)	60	7.0	35	80.7	17.3	2.54
HOEt (P)	60	1.0	5	80.2	17.5	2.62
CES (P)	60	3.2	16	89.2	18.5	3.05
Cationic	60	2.4	12	75.0	16.3	2.88
Carbamyl	60	5.6	28	76.5	16.8	2.57
Guar-Starch[a]	60	5.8	58	75.0	15.4	2.20
Guar	60	..	..	78.0	16.3	2.43
Pearl	120	5.2	26	77.0	18.1	2.82
Pearl (T)	120	7.0	35	86.7	17.9	2.57
HOEt (P)	120	1.0	5	80.0	18.5	2.45
CES	120	3.4	17	85.2	16.5	2.93
Cationic	120	2.6	13	74.9	17.1	2.60
Carbamyl	120	5.6	28	79.2	17.0	2.74
Guar-Starch[a]	120	6.4	64	76.7	17.0	2.68
Guar	120	..	..	80.5	16.6	2.43

[a] Starches added at 1% (20 lb./ton) in Deckle Box, Noble & Wood Laboratory sheet machine, bleached sulphite pulp, 650 to 700 ml. S-R freeness, rosin size 2%, pH 5.0 to 5.1.
[b] Hydroxyethyl content = 2.0%.
[c] Carboxyethyl-Na content = 2.0%.
[d] Diethylaminoethyl ether content [$CH_2CH_2N(C_2H_5)_2$] = 2.0%.
[e] Carbamyl ether content (-$CH_2CH_2CONH_2$) = 3.0 to 3.2%.
[f] Thick-boiling pearl—50%.

droxyethyl ether and a cationic dialkyl aminoethyl starch at 5 to 10% retention.

It is notable that in nearly all cases no significant change in the amount of starch in the sheet occurred after the 15- or 20-sec. level was reached. This was at a dosage level of 1% of starch on the fiber weight. The implications of this as to practical papermaking will be discussed in a later section.

Strength Versus Time of Contact with Starch Additives

In the portion of this study which involved holding the fibers in contact with the starch additives for controlled lengths of time up to 2 min., the data indicates some marked increase in burst for DMU crosslinked starch as the time of contact increases, and conversely a marked decrease for pearl starch. Carboxyethyl starch shows a maximum burst at an interval of 60 sec.

All starches examined in the time-of-contact study showed elongation increases which passed through a maximum at 20- or 30-sec. contact followed by a general marked decline.

DISCUSSION—IMPLICATION AND HYPOTHESIS

Data previously recorded in the literature have demonstrated that the sorption of various additives to papermaking fiber slurries is a diffusion process and that the energy of sorption is of the same order as that for the formation of hydroxyl-hydrogen to oxygen-hydrogen bonding (O-H---O).

The works of Pearl (*21*), Leach, (*17*), Most (*19*), and Russo (*27*) have all shown that in spite of the diffusion process which controls the sorption rate, the early stage of the sorption is quite rapid in terms of the amount of polysaccharide in pounds of additive per ton of paper fibers. Thus Russo showed that over 13 lb. of gum could be sorbed by a ton of bleached sulphite fiber in the first minute. Our present study shows that 7 to 8 lb. of starch products can be sorbed by a ton of fiber in as short a time as 15 sec. Since the amount of additive did not increase up to 120 sec., we may presume that with adequate agitation the time required to reach the maximum amount capable of being sorbed is considerably less than 15 sec. for the particular conditions of these experiments.

There is apparently something more to the problem of "how useful is a polysaccharide adhesive?" than the amount irreversibly sorbed or retained. We believe our experimental data, particularly that portion dealing with time of contact, indicates that, although the amount of starch additive in the sheet does not change, the *effectiveness* of the amount in the sheet changes as

far as Mullen, tensile, and elongation are concerned as time of contact in the aqueous medium increases.

Since the starch additive had been cooked long before it was added to the sheet fiber slurry it can be argued that any changes in efficiency are a result of *changes taking place in the additive after* a portion of the polysaccharide polymer has become attached (irreversibly?) to the surface of the cellulose fibrils.

Since the percentage of starch additive retained will be the same if only one anhydroglucose unit, or if each and every one of the anhydroglucose units, is bonded to the cellulose fibers comprising the handsheet it is obvious that the amount retained gives no clue as to the mechanism of hydrogen-bonding which is presumed to hold the additive to the fiber.

If the major portion of the polysaccharide is sorbed to the fiber surface in a parallel orientation as Shriver (*28*) has suggested for methyl cellulose, there will be little opportunity for the additive to bridge the gap from one fiber to another and thus bring about fiber-to-fiber bonding. On the other hand, if the polysaccharide is sorbed on the fibril surface by only a few of the polymer units the remainder of the polymer chain will be left extending into or dissolved in the solvent or dispersion medium, as suggested by Simha, Frisch, and Eirich (*29*). As additional time of contact is provided, the "dissolved" or "dangling" ends or segments of the polysaccharide polymer can become attached to new cellulose fibrils. While these new additive-to-fiber bonds do not increase the percentage of retention they do give increased strength to the sheet structure.

It is difficult to offer a logical explanation for the up-down-up-down sequence in five or six of the eight additives studied as the time of contact increased from 15 to 60 sec. and it is equally difficult to term these patterns purely coincidence, since three separate individual batches of pulp were concerned and the sheet preparation period extended over three days with each additive being put through the contact-time sequence before a new additive was employed. This argues for some time-dependent change in the nature of the bonding of the starch additive.

One of the more striking aspects of the results of the time-of-contact study is the maximum elongation found with seven out of the eight additives which occurred after 30 sec. contact between fiber slurry and additive.

The comparison between the retention and sheet strengths of the thin-boiling starches and hydroxyethyl ether starches of the same fluidity (therefore the same D.P.) shows that while the starch content was essentially the same for sheets treated with any given fluidity product the strength values were always slightly less for the hydroxyethyl starches. The poorer fiber-bonding power of the hydroxyethyl ethers of the thin-boiling starches may be related to possible changes in conformation brought about by the presence of the hydroxyethyl group (probably on the C_2 or C_3 position) of every thirteenth glucose unit in the starch polymer. This difference between hydroxyethyl and unmodified starch was reversed at the "pearl" -viscosity level where at equal starch content the starch-ether treated sheets were markedly better in all strength features. The degree of hydroxyethylation of the pearl variety was, however, lower here, being in the order of 1 group per 20 anhydroglucose units.

In examining the degree of retention of various starches at several dosage levels (Table VI) it is seen that in general the higher molecular weight starches are retained better than those of lower molecular weight. Various workers—among whom are Simha, Frisch and Eirich, (*29*) Barber and Ware (*2*), and Swanson (*33*)—have suggested a probable effect on retention and strength increases by molecular size and shape. A notable exception to this is the retention of the thin-boiling acetate ester starches which are retained at levels substantially higher than the parent thin-boiling starch or the hydroxyethyl ether derivative. The only explanation of this result which appears logical to us is that in the novel process used for making the acetate esters some changes in conformation have resulted which make for a higher degree of retention on the cellulose fiber.

This seems a logical point to talk about conformation and its influence on retention of polysaccharide adhesives and its possible role in determining the strengths of the fiber-to-fiber bonds created through the intermediate of the polysaccharide adhesives.

While we draw the cellulose molecule as a chain of anhydroglucose units connected by a 1,4′-glycosidic linkage we tend to forget that the glucose units are not such that all atoms in the ring are in the same plane.

The six-membered glucopyranose ring, containing five carbon atoms and one oxygen atom can exist in eight strainless forms, two of which have a chairlike structure and the remaining six a boatlike conformation (*22*).

Cellulose is considered to exist in the C1 conformation. In this conformation the hydroxyls at C_2 and C_3, and the carbinol group, —CH_2OH are all equatorially oriented.

When we come to consider the conformation of the glucose units of amylose or amylopectin, we enter a field which is still beset by controversy. In 1939, Freudenberg (*8*) suggested that the B1 conformation best represented all of the facts then known. Murakami (*20*) in 1948 proposed that the formation of the amylose-iodine complex fitted best into the concept of glucose in the C1 chair-form with one hydroxyl and the glucosidic oxygen positioned on the internal surface of a helix around the iodine atoms.

In 1954, Reeves (*23*) studied the solubility of amylose in cuprammonium solutions and postulated that the lack of solubility until the amylose had been made alkaline argued for a shift from the B1 and B3 form of Freudenberg to a C1 form under the influence of alkali. In 1957, Reeves (*24*) proposed that one must consider skewed or half-chair forms as probable structures which could exist as stable conformations under certain conditions.

More recently Storey and Merrill (*30*), Greenwood and Rossotti (*10*), and Rossotti (*26*) have shown that, at least in the iodine-complex, amylose consists of glucose units in the C1 form.

The available evidence then indicates that as far as glucose ring conformation is concerned, amylose should be capable of a good ring-to-ring "fit" at occasional intervals along the polymer chain. What remains ambiguous is the over-all shape of the amylose polymer molecule. In addition, one has the problem

of how to deal with the preponderance of the highly branched amylopectin in unmodified native starches.

The problem of the shape of the amylose molecule in solution is still largely unsolved. Arguments supporting either the helical rod or the random coil configuration appear with nearly equal frequency and supported by substantial documentary evidence. It is quite evident that complexing agents such as iodine, fatty acids and alcohols, added to amylose solutions, cause a separation of amylose in a helix configuration. It must be kept in mind that this is *not* substantiating evidence to show that the amylose *was* in a helical configuration *before* the addition of the complexing agent. Likewise the recent publication of electron micrographs of dried films of soluble starch (*12*), which show helical structures varying from 100 to 500 A. in diameter, does not prove that the colloidally dispersed polymer was in a helical configuration while in the "solution"-paste form.

Everett and Foster (*7*) have presented evidence from light scattering and viscosity data on amylose dissolved in dimethylsulphoxide, 0.33 *N* aq. KCl and 0.5 *N* KOH that amylose in these solvents is a random coil. The random coil concept fits logically into the pattern of laboratory and commercial starch retention on papermaking fibers since one would expect that the "regularity" inherent in a helix configuration for starches would produce *higher* retentions than are obtained.

Reeves (*25*), in discussing some consequences of the conformation of carbohydrate molecules wrote, "as the awesome diversity of reactivities exhibited by configurational isomers continues to unfold, the need for generalizing concepts becomes more urgent." When we add our own need to get more useful performance from the products our industry uses we are even more impressed for the need of generalizing concepts. We are surrounded by the darkness of lack of detailed knowledge of the real nature of the products we use and the absence of a mechanism to explain how they produce the results we obtain. We are, then, like the seven blind men attempting to define an elephant—it all depends on where we touch the beast.

The basic step in our own specific process of adhesion is one which many workers have well defined for us. McLaren (*18*) has said, "The polymer must first adapt itself to the surface, i.e., 'wet' the surface. This first step is a rate phenomenon entailing an orientation of dipole, polar and/or hydrogen-bonding groups at the interface." Swanson (*33*) has pointed out that, "the hydrogen-bond plays a very important role in interfiber bonding. A multiplicity of hydroxyl groups on cellulose, starch, locust bean gum, guar, etc., gives rise to many opportunities for association through hydrogen-bonding."

There is apparently something more required to create interfiber-bonding than a multiplicity of hydroxyl groups since our finding with polyvinyl alcohol (one hydroxyl for each two carbon atoms) indicated a negative effect. Perhaps one of the requirements for high level performance on the part of polysaccharide additives is that they should match as closely as possible the cellulose surfaces which they are to bond together. Starches, and other alpha-glycosidically linked polysaccharides are probably enough *unlike* cellulosic surfaces so that not only the degree of retention but the fiber-to-fiber bond strengthening efficiency is poorer than the beta-glycosidically linked polysaccharides such as locust bean and guar gums.

With starches, one apparently deals with several weaknesses in terms of molecular configuration. One factor is the presence of two molecular species, the unbranched amylose fraction and the branched amylopectin fraction. Each fraction obviously interferes with the sorption of the other fraction, since both cannot occupy the same space. The predicted early commercial availability of high amylose starch (*37*), or pure amylose (*38*) forms should permit an early determination of the benefits of that one fraction alone.

Another factor is the finding within the amylopectin fraction, the major component of most commercial starches, of substantial quantities (about 10%) of branching of a 1,3′ type rather than the 1,6′ type (*25*). Still another factor is that many papermaking pulps contain substantial amounts of mannose polymers, which are either an integral part of the cellulose polymer or a well-retained physical mixture (a point which is still in dispute).

The presence of mannans as a part of the papermaking fiber surface appears to explain in part why the galacto-mannan products show significantly better performance than equal amounts of starch-type polysaccharides.

Many interesting speculations arise when one attempts to derive a rational explanation of the sequences accompanying the use of a polysaccharide adhesive in the papermaking process. We might stimulate our imagination by trying to trace the process of interfiber bonding as benefited by an additive.

The polysaccharide adhesive is prepared for use by slurrying, suspending, mixing, "cooking" in an aqueous medium. The extent of completeness of colloidal solution of the polysaccharide is largely unknown. Various concentrations, temperature levels and cooking times are used within the industry.

If starch products are used, two molecular species, amylose and amylopectin, are present. All natural polysaccharides contain polymers having a wide range of molecular weights. A diffusion process brings the carbohydrate substance close enough to the cellulose so that an association of a portion or segment of the polysaccharide polymer takes place. We do not know the nature of the associative forces, but because of our knowledge of happenings in other fields, we attribute the initial association to hydrogen-bonding and other forces. We do not know if one hydroxyl group in the polysaccharide monomer unit which makes the initial contact with the cellulose surface is enough to bind it firmly or if it requires the more complete fit of all the hydroxyl groups (C2, C3, C6 for starches), the glycosidic oxygen bond positions, and the pyranoside ring oxygen orientation to create an irreversible bonding.

Assuming that the initial contact of the polysaccharide with the cellulose surface brings about an irreversible sorption or bonding the polysaccharide is now "trapped" and cannot escape appearing in the final dried sample of paper. It may be present as an appendage, dangling into the sheet voids or lying inert on the surface, in which case it will contribute nothing to the sheet strength.

If the sorbed polysaccharide is to be useful in increas-

ing sheet strength, it must attach itself to at least a second fiber. We must keep in mind that the second attachment does not increase the degree of retention since it is already irreversibly attached to a fiber which will appear in the final sheet. The attachment to the second fiber may take place while the fibers are still in a state of extreme dispersion, or at any time later, up to the point at which the paper is finally finished. Since the mobility of the unattached end of the "trapped" polysaccharide will decrease as the water content of the environment decreases it is unlikely that any significant amount of second attachment can take place in the later stages of drying the sheet.

The second attachment of the polysaccharide polymer could take place in solution at the most remote segment from the initial attachment. It is questionable that this type of attachment would result in substantial increases in sheet strength. It is equally unlikely that the second attachment will take place at the segment adjacent to the point of initial association, although this might be ideal for improving fiber-to-fiber bonding. In any event we then have the polysaccharide attached to two (or more) fibers so that it can truly contribute to fiber bonding.

We do not know if the best orientation for fiber-to-fiber bonding requires a parallel alignment of the polysaccharide segments with the cellulose molecular axis or if a perpendicular orientation would suffice as well.

We do not know if reinforcement of the initial fiber-to-polysaccharide-to-fiber is needed to reach optimum sheet strength.

We *do* know that the process of sorbing the polysaccharide does not stop at the initial phase. We are certain that "fresh" polysaccharide sorbs to polysaccharide in a pattern of crystallization. If the new polysaccharide attaching itself to the already "trapped" polymer is not bound at some point to a cellulose fiber the attachment will not be useful in increasing sheet strength. Likewise, if the new polysaccharide attaches to the surface of a cellulose fiber already attached to some other polysaccharide the deposition will be wasted as no new strengthening will result.

All this adds up to the many possible nonproductive associations of the polysaccharide adhesive with papermaking fiber surfaces.

SUMMARY AND CONCLUSIONS

The data gathered in this work indicates that different starch products vary in the extent to which they are sorbed onto and retained by papermaking fibers. Previous literature has also indicated differences in sorption of different varieties and modifications of starches.

Variations in sorption of polysaccharide additives may be attributed to: (a) molecular weight, (b) nature of the substituent groupings, (c) configuration of the polysaccharide in solution and speculatively, (d) differences in conformation of the polysaccharide monomer units. At equal levels of sorption among the thick-boiling starches the presence of a hydroxyethyl group (which is presumably on the C2 or C3 hydroxyl as opposed to the C6 hydroxyl) increases the test results. It is known that the amount of substituent present is enough to prevent any appreciable retrogradation of amylose in a linearly-associated insoluble form. The more accessible hydroxyl at the end of the ether substituent may make it possible to bind more fiber with the same amount of starch.

Among the thin-boiling starches there was no improvement in strength of the sheet when a hydroxyethyl group was introduced. A marked improvement was obtained when the substituent was an acetyl group rather than a hydroxyethyl. This may be due to the increased hydrogen-bonding capability introduced by the carbonyl function.

Within the limits of the dosage rate studied, that is, up to 2% additions on the weight of the fibers, there was no indication of "saturation" of the fiber surfaces as some workers have indicated.

It is interesting to note that for the unmodified, or unsubstituted starches, pearl, thick-boiling starch—the percentage of the added starch which was retained was essentially the same at all levels of addition.

On the other hand, all of the starches to which substituents or chemical modification have been introduced were increasingly less well-retained as the dosage level rose. This is most probably due to the lowered tendency of the modified or substituted starches to associate with themselves or to crystallize. The higher degree of retention at the lower dosage level argues that most of the deposition is on a fiber surface and results in substantial increases in sheet strength over the sheet with no additive. The deposition of a second increment of starch additive at the higher dosage level produces a very much smaller increase in sheet strength which can be rationalized as due largely to nonproductive sorption on the already present polysaccharide or on a fiber surface without change in the amount of bonded area.

When a detailed examination is made of the effect of hydroxyethylation of thin-boiling starches (of comparable alkali fluidity) it is found that at equal levels of starch content the hydroxyethylated member of a pair gives lower burst, tensile, and elongation than the thin-boiling base.

When the beaten and already sized fibers were held in contact with guar solutions for 2 or 3 hr. and then used to test the retention of starches, and their efficiency in producing strength increases, the results were quite different from what occurs if starches alone are used. First, when added to pulps having been treated with 0.25% (5 lb. per ton) of guar at levels of 0.25% (5 lb. per ton) for each starch the retention of pearl, hydroxyethyl pearl, 90 fluidity thin-boiling, and the hypochlorite oxidized starch were considerably higher than if no guar pretreatment were used. Retention of the crosslinked, thick-boiling starch, the hydroxyethylated, thin-boiling and the acetate, thin-boiling starches was considerably reduced. Burst was for the most part only slightly different or in some instances even decreased. However, tensile and elongation were appreciably increased.

When the level of guar pretreatment and the dosage of starches was increased to the 0.5% (10 lb. per ton) level the retention of all starches except pearl and hydroxyethyl pearl was *lower* than if no guar pretreatment were used. It seems that at the 0.5%-level guar hinders the deposition of almost all starches. While the burst values were all higher than at the 0.25% level of double treatment, the tensile strengths were

lower or unchanged and the elongation was likewise *lower*. These findings suggest that the most useful way to apply combinations of natural gums and starches may be in adding relatively small amounts of natural gums to the fiber slurry quite far back from the sheet formation process (wire or cylinder) followed by the addition of starches later at a point where the sorption can have time to give the optimum results.

When the point of addition of the starch adhesives was changed from the proportioner box, where considerable contact time (10 to 15 min.) is normal, to the deckle box where the contact time was varied from 15 to 120 sec., the percentage of retention of pearl or hydroxyethyl pearl was considerably decreased even with up to 2 min. of contact time. The strength increases caused by the amounts of starch retained during the short contact time were, however, surprisingly higher than for the same level of starch at longer contact time.

The retention of the thick-boiling cross-linked starch was not as much reduced by the short contact time. When a combination of equal parts of guar gum and the thick-boiling starch was used, the retention of starch in 15 sec. contact was 60%, identical to the retention of the same dosage level of this starch after long contact without the guar. This reproduces and confirms the level of retention of starch in this combination reported in a previous paper. It should be noted that the high level of starch retained in the short contact time was not effective in raising the strength values.

When several pearl-type starches containing various different ether substituents were examined for rate and level of sorption upon papermaking fibers the following order of retention with increasing time was found:

Starch Type	*Time of Contact, Sec.* 15	20	30	60	120
Carbamylethyl ether, %	36	27	27	28	28
Pearl starch, %	23	25	27	28	26
Carboxyethyl ether, %	17	16	17	16	17
Hydroxyethyl ether, %	11	11	6	5	5
Diethylaminoethyl ether, %	10	11	11	12	13

In summary, the work presented here has shown the following major points which are of interest for a fuller understanding of the function of polysaccharide adhesives in fiber-to-fiber bonding:

1. Starches added to the wet-end are retained in the final sheet at levels which depend upon (a) molecular weight, (b) presence or absence of substituent groups, (c) nature of the substituent group, (d) degree of beating or refining (swollen surface?) of the fibers, (e) time of contact with the fibers, (f) presence or absence of other carbohydrates. Generally speaking, the longer the chain-length of the polysaccharide the higher the level of retention, but at low levels of dosage the presence of certain groups may increase the retention of shorter-chain starches to the level of the longer chain (pearl types).

2. At the same given level of starch content the strength of the sheet depends upon the (a) nature of the starch adhesive, (b) molecular weight, and (c) nature of the substituent groups present.

The work has revealed more of the extent of the area of the unknown in the role of polysaccharides in promoting fiber-to-fiber bonding. The data we have accumulated challenge us to find tools and techniques for getting a more precise understanding of how polysaccharide adhesives attach to fiber surfaces and how the attachments can be made more useful in the papermaking process. An equally intriguing challenge is presented to the polysaccharide supplier industry to devise manufacturing processes to make adhesives which will be more rapidly and more completely sorbed upon paper fibers and ones which are more effective in increasing sheet strength.

Finally, it is our hope that this work will encourage more questions to Mother Nature and more attempts to translate the answers she gives.

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ASSOCIATION NEWS AND EVENTS

National Conferences

Forty-Fifth Annual Meeting, Hotel Commodore, New York, N. Y., Feb. 22–25, 1960.

Eleventh Coating Conference, Edgewater Beach Hotel, Chicago, Ill., May 23–25, 1960.

Pulp Bleaching Conference, Edgewater Beach Hotel, Chicago, Ill., June 14–16, 1960.

Fourteenth Alkaline Pulping Conference, Multnomah Hotel, Portland, Ore., Aug. 22–24, 1960.

Forest Biology Conference, Seattle, Wash., Aug. 24–27, 1960.

Eleventh Testing Conference, Pantlind Hotel, Grand Rapids, Mich., Sept. 27–29, 1960.

Tenth Corrugated Containers Conference, Royal York Hotel, Toronto, Canada, Oct. 10–13, 1960.

Fifteenth Plastics-Paper Conference, Hotel Syracuse, Syracuse, N. Y., Oct. 17–19, 1960.

Fifteenth Engineering Conference, Robert Meyer Hotel, Jacksonville, Fla., Oct. 24–28, 1960.

Local Section Meetings

Pacific: Jan. 12, 1960, Longview, Wash., "Engineering"; April 15, 1960, Everett, Wash., Shibley Award Meeting; May 5–7, 1960, Bellingham, Wash., or Harrison Hot Springs, Annual Meeting; September, 1960, Salem, Ore., "Modernization."

Golden Gate District (Pacific Section): Jan. 26, 1960, Visit to California Forest Products Laboratory, 3:30–4:00 p.m., Dinner at Hotel Claremont 6:00 p.m. Mar. 29, 1960, "Recent Advances in Materials Handling," 4:00 p.m. mill visit to Nulaid plant, dinner at Cottage Restaurant, San Leandro 6:00 p.m. May 10, 1960, True Memorial Lecture, Hotel Claremont, Berkeley.

Lakes States: Jan. 12, 1960, mill visit Paper Converting Machinery Co. and Bay West Paper Co., Green Bay; dinner at Northland Hotel, Green Bay. Theme: "High Velocity Paper Machines." March 8, 1960, mill visit Bergstrom Paper Co., Neenah; dinner at Menasha Elks Club. Theme: "Statistical Methods Applications in the Paper Industry." April 12, 1960, dinner location to be announced. Theme: C. J. West Awards. May, social meeting—date to be announced.

Delaware Valley: Jan. 21, 1960, Engineers Club, Philadelphia, Pa., Operations Research Panel; March 26, 1960, Benjamin Franklin Hotel, Philadelphia, Pa., 1960 Philadelphia Graphic Arts Conference; April 28, 1960, Engineers Club, Philadelphia, Pa., E. J. Albert Award Program; May 27, 1960, Beliot Eastern, Downingtown, Pa., tour and outing.

Kalamazoo Valley: Jan. 21, 1960, Harris Hotel, Kalamazoo, Papermakers' Get-Together; March 17, 1960, Inman's Restaurant, Galesburg, "Graphic Arts"; April 21, 1960, Inman's Restaurant, Galesburg, "Stock Preparation"; May 12, 1960, Harris Hotel, Kalamazoo, Recognition Night, WMU Awards; June 21, 1960, Annual Golf Outing, Gull Lake Country Club.

New England: April 8, 1960, Management Night; June 3–4, 1960, Chatham Bars Inn, Chatham, Mass., Spring Meeting.

New England (Eastern District): Armand's Restaurant, Route 9, Framingham, Mass.: Jan. 11, 1960; March 14, 1960.

Ohio: Jan. 12, 1960, Manchester Hotel, Middletown, Ohio, "Clupak." Speaker: C. A. Shoudy. Feb. 11, 1960, Colony Restaurant, Swifton Center, Cincinnati, Ohio, plant tour through Formica, a division of America Cyanamid. March 15, 1960, Manchester Hotel, Middletown, Ohio, "Two-Phase Flow in a Wet Web." Speaker: Joe Parker, Beloit Iron Works. April 12, 1960, Miami University, Oxford, Ohio, a tour of the new Paper School. Subject: "High Polymers." Speaker: H. E. Whitacre. May 12, 1960, Hartwell Country Club, Cincinnati, Ohio, Ladies night.

Ohio (Indiana District): Jan. 19, 1960, Marott Hotel, Indianapolis, Ind., "Coating," Speaker: William H. Aiken, Diamond National Corp. Feb. 16, 1960, Plant Tour To be announced. March 15, 1960, Marott Hotel, Indianapolis, Ind. Panel Discussion, To be announced. April 19, 1960, Plant Tour, To be announced, "Coating," Brage Golding, Purdue University. May 17, 1960, Marott Hotel, Indianapolis, Ind., "Testing," Arthur Dreshfield, The Glidden Co.

Empire State: Whiteface Inn, Whiteface, N. Y., June 10–11, 1960.

Empire State (Metropolitan District): 465 Lexington Ave. New York, N. Y. Jan. 12, 1960, "High Velocity Drying" *(Executive Night);* March 8, 1960, "Coating"; April 12, 1960, "Packaging"; May 13, 1960, Ladies' Night.

Empire State (Northern District): Woodruff Hotel, Watertown, N. Y. Jan. 14, 1960, Students' Night; Feb. 11, 1960, Color: March 10, 1960, Strength Developments in Paper; April 14, 1960, Junior Award Night; May 12, 1960, Annual Ladies Night.

Empire State (Central District): University Club, 431 E. Fayette St., Syracuse, N. Y.

Empire State (Western District): Prospect House, Niagara Falls, N. Y.

Empire State (Eastern District): Queensbury Hotel, Glens Falls, N. Y. Jan. 21, 1960, Executives Night; Feb. 18, 1960, "Synthetic Fibers" (tentative); March 17, 1960, Junior Awards Contest; April 21, 1960, Symposium, "Wet End Machine Operation"; May 21, 1960, Annual Ladies' Night.

Maine-New Hampshire: June 17–18, 1960, Mountain View House, Whitefield, N. H., Annual Meeting.

Chicago: Chicago Bar Association, 29 S. LaSalle St., Chicago, Ill. Jan. 5, 1960, Webfed Offset Printing; Feb. 2, 1960, Adhesives; March 1, 1960, Folding Cartons; April 5, 1960, Corrugating; May 3, 1960.

Lake Erie: Jan. 21, 1960, Cleveland Engineering and Scientific Center, Conference on Pulp and Paper Testing Equipment and Methods Including Laboratory Coating and Sheetmaking Techniques; Feb. 18, 1960, Colton Chemical Co., 6626 Union Ave., Cleveland, Ohio, plant tour; March 17, 1960, Cleveland Engineering and Scientific Center, "Off-Machine Coating with Emphasis on Waxing and Barrier Types and Base Paper Requirements."

Southeastern: Jan. 22–23, 1960, Jacksonville, Fla.; March 18–19, 1960, Columbia, S. C.; May 20–21, 1960, Savannah, Ga.

Gulf Coast: Jan. 29, 1960, Stafford Hotel. Tuscaloosa, Ala.; March 18, 1960, Core Hotel, Panama City, Fla.; May 13, 1960, New Orleans, La.

Delaware Valley

The Delaware Valley Section announces "The 1960 Philadelphia Conference of the Graphic Arts Industry" to be held on Saturday, March 26, 1960, at the Benjamin Franklin Hotel in Philadelphia from 8 a.m. to 5 p.m.

The Saturday date has been selected on recommendation from representatives of the Philadelphia Litho Club and the Philadelphia Printing Ink Makers Products Club for the convenience of their members to attend.

This will be the third consecutive Annual Graphic Arts Conference sponsored by the Delaware Valley Section and will be the first time a full day's program has been planned.

Enthusiastic reactions to the previous two conferences indicates that this bigger and better conference will also be successful and point the way to further growth and a regular annual event of far reaching interest.

Since the Philadelphia area is generally accepted as the birthplace of both the printing and papermaking industries in this country, and continues to be an important center for both these industries, it is an ideal location for holding these conferences.

Annual Meeting Personnel Service

To assist companies recruiting technical men in publicizing their personnel needs, a "Personnel Service" room will be provided at the Hotel Commodore during the 1960 Annual Meeting. Company members of the Association may post descriptions of their openings in this room which will be available to all delegates. This service was initiated at the 1959 meeting and is being repeated at the request of the companies which participated.

Interested corporate and sustaining members are asked to forward brief position descriptions to the Association office by Feb. 15, 1960. These descriptions which will be displayed on bulletin boards in the "Personnel Service" room on Monday through Wednesday, February 22–24, should include the name and address of a company representative who may be approached if additional information or an interview is desired. Companies planning to have a personnel representative at the Annual Meeting may add his name and hotel room number to the descriptions after he has arrived in New York. If the position descriptions of any one company cover more than a single sheet, the subsequent pages will be posted behind the first sheet on the bulletin boards.

The Association's role in this activity is expressly limited to providing the area to its company members without charge, supplying an attendant, and publicizing the location of the room in the program booklet and on the conference bulletin boards.

Forty-Fifth Annual Meeting

The 45th Annual Meeting of the Technical Association of the Pulp and Paper Industry will be held at the Commodore Hotel, New York, N. Y., on Feb. 22–25, 1960.

Members of the Association should remember to bring to the meeting their 1960 membership cards since the lower registration fee will be limited to individuals who can present their 1960 cards. Registration will be speeded if members have their cards with them. All individuals attending the Annual Meeting are expected to register.

The following is a *tentative* technical program for the Annual Meeting and is *subject of further change.*

PROGRAM

MONDAY, FEB. 22, 1960

10:00 a.m. Annual Meeting (East Ballroom)

TUESDAY, FEB. 23, 1960

Morning
- Fourdrinier
- Acid Pulping I
- Cylinder Board I
- Pulp Purification I
- Water I

Afternoon
- Corrugated Containers I
- Acid Pulping II
- Cylinder Board II
- Structural Fibrous Materials
- Water II

WEDNESDAY, FEB. 24, 1960

Morning
- Corrugated Containers II
- Graphic Arts I
- Dissolving Pulps I
- Pulp Purification II
- Statistics I

Afternoon
- Corrugated Containers III
- Graphic Arts II
- Dissolving Pulps II
- Alkaline Pulping
- Statistics II

THURSDAY, FEB. 25, 1960

Morning
- Agricultural Fibers
- Corrosion
- Chemical Products
- Mechanical Pulping

Preparation of Projector Slides

Occasionally authors are unable to locate local photographers who can prepare projector slides needed in the presentation of Annual Meeting papers. To assist such authors the headquarters office will be pleased to receive orders for slides. These will be forwarded to a New York photographer whose charge for each slide will be:

Size, in.	*Black and White*	*Color*
2 by 2	$1.50	$3.00
$3\frac{1}{4}$ by 4	2.50	5.00

There will be no charge by the Association for its assistance in this matter, but the photographer's fee must be paid by the author. The slides will become the property of the author.

Orders must be accompanied by the finished drawings ready for reproduction. Any material requiring further drawing before photographing will not be accepted.

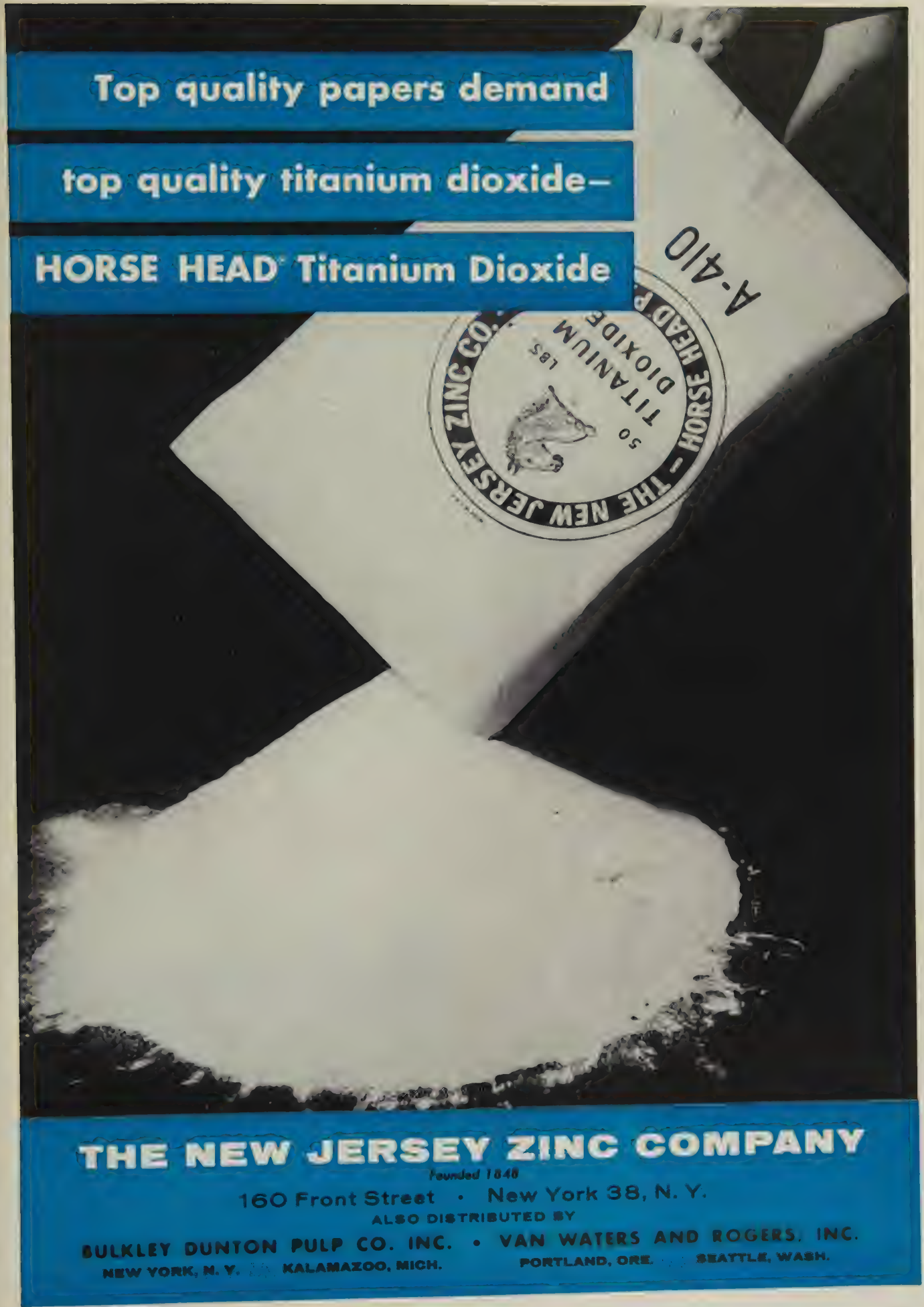
Authors interested in utilizing this service are urged to submit their requests and copy promptly, so that the slides can be produced well in advance of the Annual Meeting.

1960 TAPPI Medal Award

The Executive Committee has unanimously selected L. E. Wise, The Institute of Paper Chemistry, Appleton, Wis., as the recipient of the 1960 TAPPI Medal. The presentation will be made at the 45th Annual Meeting to be held in New York on Feb. 22–25, 1959.

Louis Elsberg Wise was born on Jan. 29, 1888, in New York City. His formal education was obtained at Columbia University where he graduated in 1907 with an A.B. degree and membership in Phi Beta Kappa. In 1911 the Ph.D degree was conferred upon him: his Doctor's thesis was carried out under the direction of Marston Taylor Bogart; and he was elected to Sigma Xi.

Dr. Wise was employed briefly in 1912 at the Standard Varnish Works on Staten Island where he first became in-


Top quality papers demand
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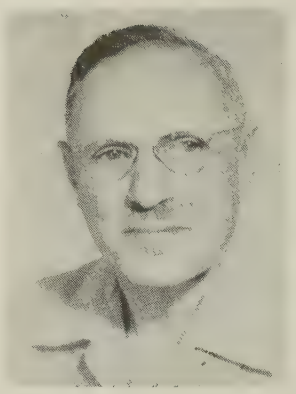
terested in the resins and other extraneous materials of wood. But his interest in teaching proved to be more compelling than varnish making and he returned to Columbia University in 1912 to 1913 as an instructor in biochemistry. The following year, 1913 to 1914, he became an instructor in chemistry at the University of Missouri. From 1914 until 1915 he was a biochemist at the Bureau of Chemistry, United States Department of Agriculture, and from 1915 to 1918 was associated with the Bureau of Plant Industry. During World War I he worked as a research chemist with the Bureau of Aircraft Production for one year. In 1919 he was appointed to the post of Professor of Forest Chemistry and Head of the Department of Forest Chemistry at The New York State College of Forestry at Syracuse.



L. E. Wise, recipient of the TAPPI Gold Medal, 1960

In the course of his duties, Professor Wise was instrumental in activating the Department of Pulp and Papermaking at the New York State College of Forestry together with his colleague, Clarence E. Libby, and contributed much to the development of this department and in the training of many men destined for the pulp and paper industry.

On sabbatical leave in 1926 to 1927, Dr. Wise studied at the Pasteur Institute in Paris under Professor Bertrand.

Illness suddenly forced his retirement in 1932. He located in Winter Park, Fla., and began a period of convalescence. He was appointed Professor of Organic Chemistry at Rollins College in Winter Park from 1933 to 1937 on a limited schedule. In 1941, Professor Wise became Research Associate at The Institute of Paper Chemistry in Appleton, Wis. In 1957 he was made Senior Research Associate, a position he holds at the present time.

In addition to his many educational contributions to the pulp and paper industry, Dr. Wise has published more than 127 papers and books on the subjects of wood chemistry, cellulose, hemicelluloses, and carbohydrates. He has a worldwide reputation as a result of his widely used monographs on "Wood Chemistry." The 1st edition was published with the late L. F. Hawley of the Forest Products Laboratory in Madison in 1926. This was completely rewritten as a new monograph with 14 other authors, besides the editor (L. W.). The 2nd edition of the new monograph edited with E. C. Jahn, appeared in 1952.

Dr. Wise is a member of TAPPI, The American Association for the Advancement of Science, The American Chemical Society of which he has been a member for 51 years, and the Wisconsin Academy of Science, Arts, and Letters.

Executive Committee Meeting

The Executive Committee of the Technical Association of the Pulp and Paper Industry met in the Commodore Hotel on Monday, Sept. 28, 1959, at 9:30 a.m.

Members of the Executive Committee in attendance were J. R. Lientz, H. M. Annis, B. T. Briggs, P. S. Cade, K. G. Chesley, F. P. Doane, Jr., J. H. Heuer, J. J. Koenig, L. G. Rolland, H. O. Ware, and J. P. Weidner. J. L. Parsons, chairman of the Research Appropriation Committee, A. Abrams, chairman of the Administration Committee. P. E. Nethercut and R. G. Macdonald of the headquarters staff were also present.

Association Incorporation

R. G. Macdonald reported on a study made on the advisability of incorporating the Association. It recommended that incorporation be postponed until there was an evident need for such action. The Executive Committee voted to accept the recommendation that the Association should not consider incorporation at this time.

Liability Insurance

P. E. Nethercut described the need for liability insurance to cover claims for damages occurring in the headquarters office and at the meetings of the Association.

The Executive Committee authorized the secretary to obtain appropriate liability insurance for the office area and for Association meetings.

Review of Financial Statement and Preliminary 1960 Budget

The Association Balance Sheet dated Aug. 31, 1959, and the Statement of Income and Expenses for January–August, 1959, were presented. A projected statement of 1959 income and expenses indicated that the Association would finish the year with a favorable balance. (Subsequent appropriations authorized later in the meeting will reduce this balance, but a modest surplus is still anticipated.)

A preliminary 1960 budget was presented for discussion, but no action was taken at this time.

Association Research Policy

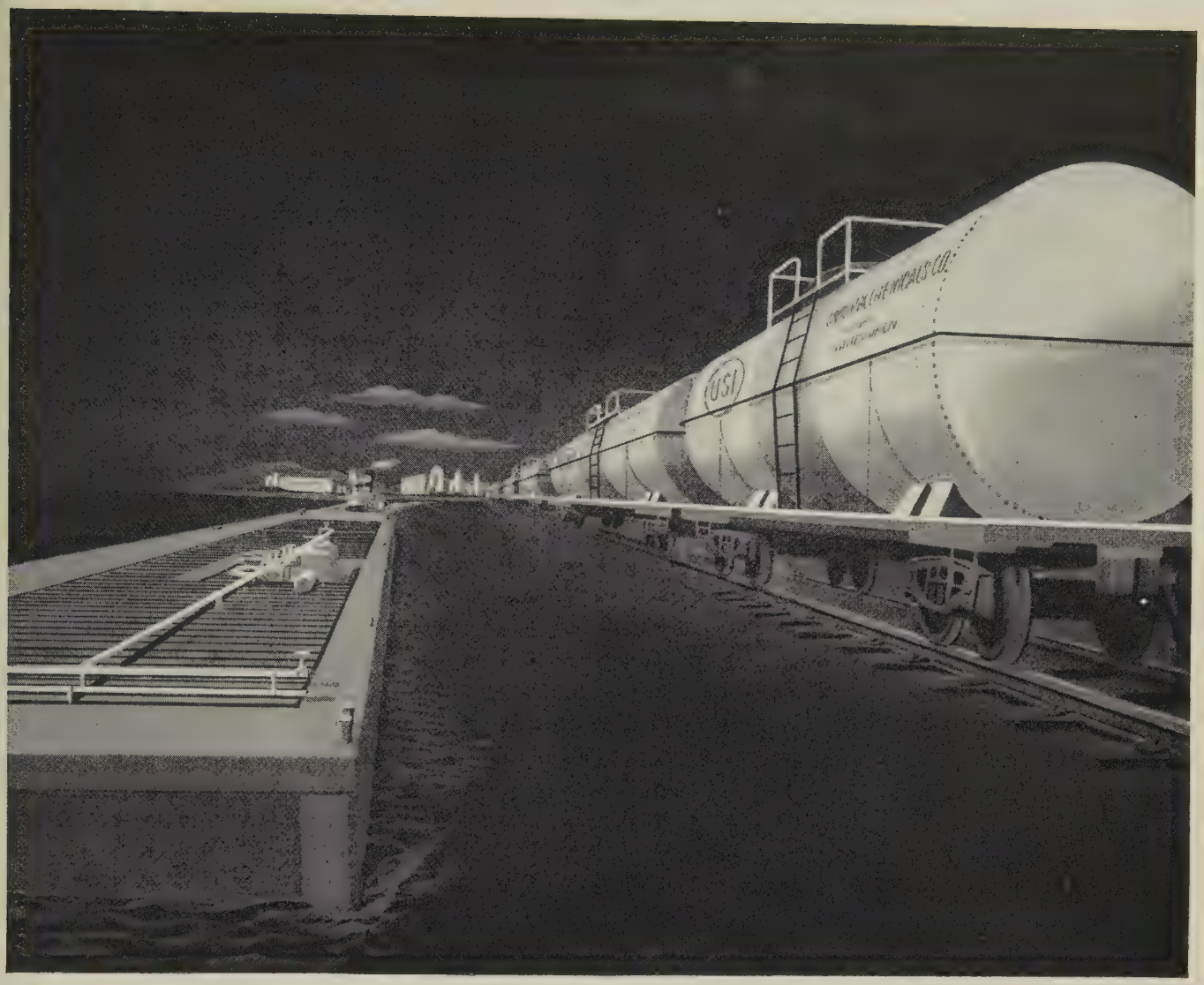
J. L. Parsons, chairman of the Research Appropriations Committee, described the research policy survey undertaken by J. R. Curtis, chairman, J. H. Heuer, F. S. Klein, and J. L. Parsons. This research committee had been appointed by J. R. Lientz at the Feb. 22, 1959, meeting of the Executive Committee to review TAPPI's research activities and objectives.

After lengthy discussion the recommendations of this committee were accepted substantially as submitted, except that Item 1c was modified by the addition of the phrase "as allocated by the Executive Committee."

On a motion by J. H. Heuer, seconded by H. O. Ware, the Executive Committee voted approval of the following recommendations:

1. This report be adopted as the current specification of TAPPI policy regarding research and project activities. In summary, the principal features covered are:
   a. Continued acceptance of 1957 "Statement of TAPPI Research Policy" as broadly covering all TAPPI project activities.

Executive Committee Meeting, Sept. 28, 1959. Seated (left to right): L. E. Rolland, R. G. Macdonald, H. M. Annis, J. R. Lientz, P. E. Nethercut, A. Abrams. Standing (left to right): F. P. Doane, Jr., K. G. Chesley, J. P. Weidner, P. S. Cade, J. H. Heuer, J. J. Koenig, H. O. Ware, B. T. Briggs. Not in picture: J. R. Curtis, W. C. Bloomquist, F. S. Klein



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Two U.S.I. plants, conveniently located at Huntsville, Alabama, can now supply your chlorine and caustic needs.

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- Your orders will arrive at a U.S.I. plant almost as soon as they leave your own—through U.S.I.'s automated order-handling system based on an extensive teletype network.
- Your orders will be delivered rapidly and without complications — because of the convenience of the Huntsville location and the efficiency of the order-handling system.
- You'll be working with a 50-year old chemical manufacturing company with a reputation of service to its customers throughout that half century.
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Liquid chlorine is shipped from Huntsville in tank cars. Commercial grade 50% liquid caustic soda is shipped in tankcars, tank trucks, barges. Other U.S.I. plants supply sodium peroxide, ammonia, polyethylene.

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We'd like to know more about U.S.I.

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U.S.I. INDUSTRIAL CHEMICALS CO.
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b. TAPPI support, at this time, of Short Range Program of Committee Project activity only.
c. Short Range Committee Project Program financial support from dues from corporate and sustaining members only, as allocated by the Executive Committee.
d. No substantial increase in current level of project activity and no change in Corporate and Sustaining dues at this time.
e. Change title of Research Appropriations Committee to more general "TAPPI Project Appropriations Committee."
f. No carryover of appropriated project funds past specified time limit.
g. Appointment of Research Advisory Council, by president, to define and develop a major long range TAPPI research program to be supported by industry.

2. Division and committee chairmen be advised to exercise better control over projects covered by TAPPI appropriations. The appointment of divisional "Project Advisory Committees" and the use of specific policies similar to those in the Engineering Division Policy Manual are strongly urged.
3. For the benefit of the membership this report, if accepted, be given general publicity at the February, 1960, Meeting in New York, and in *Tappi*.
4. At an appropriate time the president initiate a study to develop TAPPI policy regarding patents resulting from TAPPI projects and research work.
5. At an appropriate time the President initiate a study to consider the merits of the various methods of administrating long range TAPPI research, e.g., Research Foundation, Project Appropriations Committee, etc.

The Research Committee was warmly praised for the excellence of its report and its recommendations.

Research Foundation

R. G. Macdonald described the advantages and disadvantages of establishing a TAPPI research foundation which might enable the Association to undertake a broader research program than is presently possible. His report recommended that a research foundation should not be established at this time.

The Executive Committee voted to accept the recommendation that a research foundation should not be established at this time and to refer the matter to the Research Advisory Council, when this group is appointed.

The secretary was requested to send copies of R. G. Macdonald's report to all members of the Research Appropriations Committee (henceforth to be called the Project Appropriations Committee).

Association Patent Policy

R. G. Macdonald summarized the opinions and recommendations presented in his Sept. 10, 1959, report on TAPPI patent policy.

It was voted that there be no change in TAPPI's current policy of merely presenting our project results to industry through publication, until such time as TAPPI is ready to approach industry for its support of a truly long range research program. At this time the question of patents should be resolved in such a manner as to favor those companies supporting the research program.

Research Appropriations Committee Report

J. L. Parsons, chairman of the Research Appropriations Committee, reported that his committee had approved seven project proposals in April, leaving an uncommitted balance of $7704 of the original 50,000 allocation. Proposals to be reviewed by his committee in October would require, if approved, an expenditure of roughly $20,100.

The Executive Committee voted to allocate an additional $12,500 to the Research Appropriations Committee for use, if necessary, in the October, 1959, review of project proposals.

A proposed outline of a report on TAPPI research programs was submitted. The headquarters staff was asked to prepare a report on this subject for publication in *Tappi* and for the distribution of reprints to pulp, paper, and allied companies.

Tappi Medal Winner

K. G. Chesley reported on the study made by the 1960 Awards Committee consisting of K. G. Chesley, chairman, W. C. Bloomquist, P. S. Cade, F. P. Doane, Jr., and H. O. Ware. The committee recommended that L. E. Wise be the 1960 recipient of the TAPPI Medal.

The Executive Committee voted unanimously to award the 1960 TAPPI Medal to L. E. Wise.

The secretary was directed to distribute letter ballots on this matter to all Executive Committee members.

Local Section Rebate Policy

H. O. Ware reviewed the activities of the Rebate Policy Committee (H. O. Ware, chairman, B. T. Briggs, and J. P. Weidner) and asked that a decision on the broad question of rebate policy be deferred until the recommendations of the Local Sections Operations Committee had been received.

The Executive Committee was asked, however, to take affirmative action on two rebate matters of immediate concern: (1) raising the rebate level from $1.50 to $2.00 per eligible member to correspond to the 1959 increase in individual dues, and (2) authorize rebates for the Italian Section. The Executive Committee voted to authorize these two changes.

Report of the Investment Advisory Committee

The advisability of investing a portion of the Association's checking account funds in short-term interest-bearing government notes was discussed. The secretary was authorized to proceed with the purchase of these notes.

New Office Quarters

J. R. Lientz, A. Abrams, and P. E. Nethercut described the discussions and investigations which had preceded the July 22, 1959, signing of a 10-year lease for the 17th floor of 360 Lexington Ave. The Executive Committee voted to approve the 10-year lease for the new office quarters and to appropriate the sum of $23,145 to cover the expenditures involved in this move.

Magazine Title

The advantages and disadvantages of *Tappi* as the name of the Association's magazine were discussed.

The Executive Committee voted to retain the present title and to change only the wording on the cover band from "Published by the Technical Association of the Pulp and Paper Industry" to "The Journal of the Technical Association of the Pulp and Paper Industry."

European TAPPI Activities

P. E. Nethercut described the 1959 European Study Group meeting at Noordwijk in the Netherlands. Without formal action by the Executive Committee it was agreed that no action should be taken at this time on requests for financial assistance to the European Study Group.

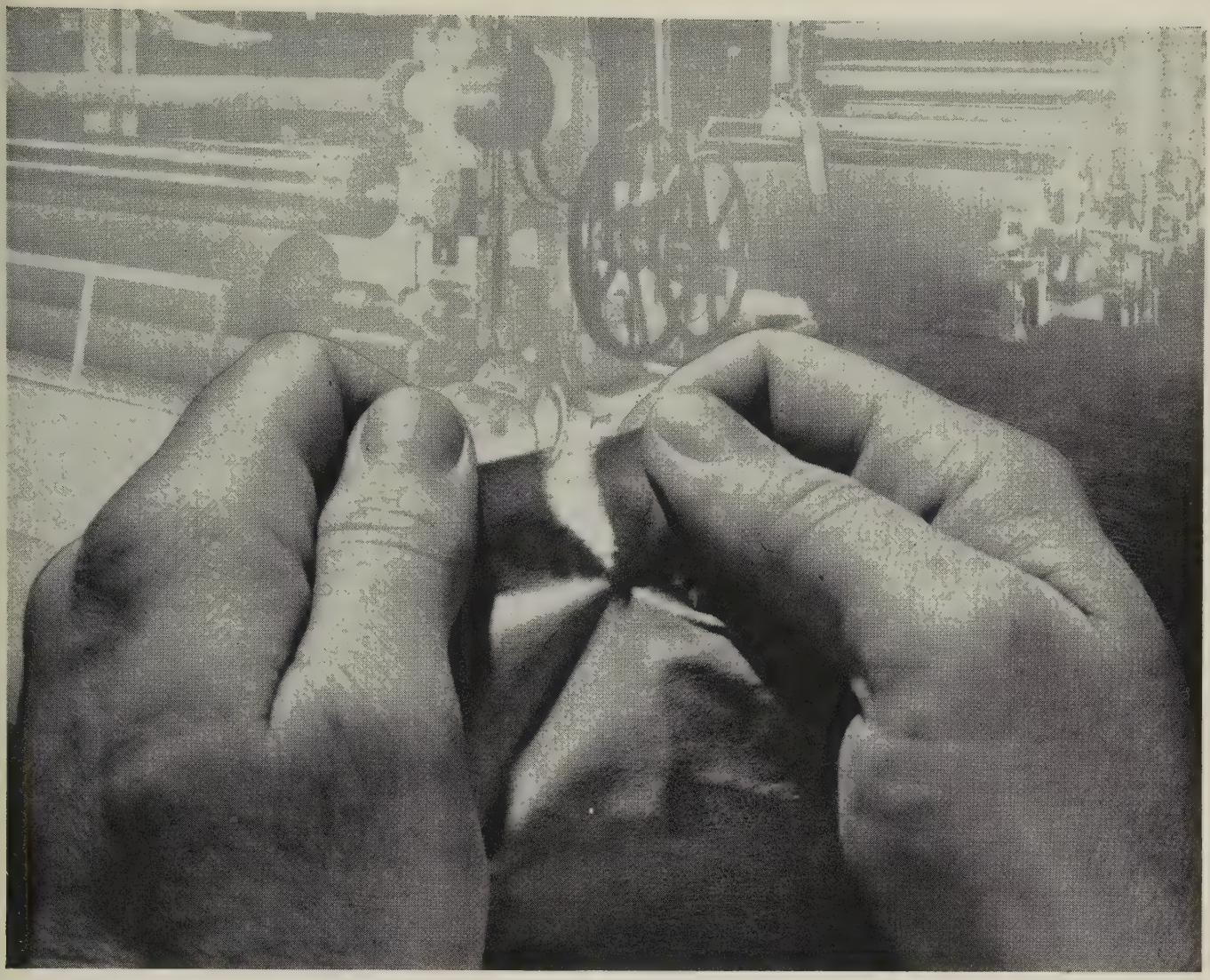
International Standards Organization

P. E. Nethercut described the activities of the International Standards Organization and the recommendation which the TAPPI and APPA headquarters staffs had jointly drafted on the activity of the United States in ISO Committee TC-6 on Paper.

The Executive Committee voted that TAPPI submit the following recommendation to the American Standards Association:

"We recommend to ASA that the U. S. adopt participating status in ISO/TC-6 subcommittee 1 and 2, and observer status in subcommittees 3, 4, and 5, with the following provisions:

1. Our understanding of the scope of the work of subcommittee 1 is that it is confined to qualitative definitions of terms used in the paper trade of the type to be found in *The Dictionary of Paper*, but not quantitative definitions aimed at product specifications.



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UFORMITE 700

2. Our understanding of the scope of the work of subcommittee 2 is that it is confined to the standardization of testing procedures, but does not include numerical specifications of product quality."

Relations with the U.S.S.R.

The questions of handling possible requests from Russians for TAPPI membership or for TAPPI assistance in arranging for visits to U. S. mills were discussed. It was agreed that no policy should be established at this time, since the international situation may change quickly. If such requests are received, they will be referred to the Executive Committee and, if necessary, to the U. S. State Department for appropriate direction.

Proposed Amendments of the Association Constitution

Two proposed amendments of the Constitution were presented to the Executive Committee for consideration:

1. To eliminate the "Overseas Members" class of membership and grade all members on the basis of their technical experience rather than partly on the basis of geography. Charge members living outside of North America and United States possessions an annual mailing fee of $5.
2. To change the title of "Secretary-Treasurer" to "Executive Secretary."

The Executive Committee voted approval of these amendments and requested that the Secretary have legal counsel approve the wording and legality of the proposed amendments before they are submitted to the voting membership of the Association. The secretary was asked to prepare an explanatory letter to be mailed to the voting members with the notice of the proposed amendments.

Legal Counsel

The circumstances in which legal counsel might be desired by the Association were reviewed. It was agreed that TAPPI's needs for legal counsel were probably too infrequent to justify payment of a retainer fee. The secretary was asked to make suitable arrangements for legal counsel on a per diem basis.

Membership Promotion

J. R. Lientz announced that a Membership Services Committee will be appointed to study services and membership promotion activities. This committee will submit its recommendations to the Executive Committee at the February, 1960, meeting.

Membership Application Forms

P. E. Nethercut proposed a number of minor changes in the format and wording of the membership application. The Executive Committee voted to approve the modified version of the membership application forms.

Career Guidance Activities

H. O. Ware described the activities of the Joint APPA-PIMA-TAPPI Guidance Committee and submitted a dummy copy of the recruiting brochure prepared by TAPPI under the guidance of H. O. Ware and A. J. Winchester. Plans for the printing and distribution of this TAPPI brochure were discussed, and an appropriation of $11,000 to cover the cost of printing 50,000 copies was requested.

The Executive Committee voted to authorize the expenditure of $11,000 for printing 50,000 copies of the recruiting brochure.

1960 Annual Meeting Plans

P. E. Nethercut described a survey undertaken to determine the effectiveness of the "Personnel Service" Room as an aid to company members seeking new personnel at the 1959 Annual Meeting.

The Executive Committee agreed that a "Personnel Service" Room should be provided for company members at the 1960 Annual Meeting and that its location should be publicized better then was possible at the 1959 meeting.

It was further agreed that the presentation of the TAPPI Medal would be the principal feature of the Annual Luncheon and that no additional speaker would be secured for this function.

Staff Personnel Needs

The need for an additional technical man on the headquarters staff was discussed, and a tentative job description for this man was circulated.

The Executive Committee voted to authorize the employment of an additional technical assistant on the headquarters staff.

Annual Report

The need for an annual report to the membership was discussed. It was agreed that the staff should prepare such a report for publication in *Tappi* and for distribution as a separate report to the members. This report would include a brief summary of 1959 highlights and would not replace the more detailed and statistical presentation which traditionally appears in the March issue of *Tappi*.

Executive Committee Representation at TAPPI Meetings

J. R. Lientz stressed the importance of attendance by Executive Committee members at functional conferences and local section meetings. A schedule of these meetings for the next six months was distributed.

Review of Five-Year Forecast

J. R. Lientz asked that the members of the Executive Committee review the Five-Year Forecast prior to the February, 1960, meeting. The staff will prepare a progress report on this forecast for presentation and discussion at that meeting.

Appointment of Tellers Committee

J. R. Lientz announced that the 1960 Tellers Committee would be appointed shortly after the meeting from a slate of candidates suggested by the secretary.

Local Section Charter Petition

J. J. Koenig presented a petition for a local section charter from the St. Louis District of the Chicago Section.

It was pointed out that such petitions are normally reviewed first by the Local Sections Operations Committee prior to submission to the Executive Committee. The Local Sections Operations Committee will meet in Kalamazoo in November, and this petition will be presented for consideration at that time. In order to expedite the processing of this petition, however, the Executive Committee was asked to indicate its approval or disapproval at this September meeting.

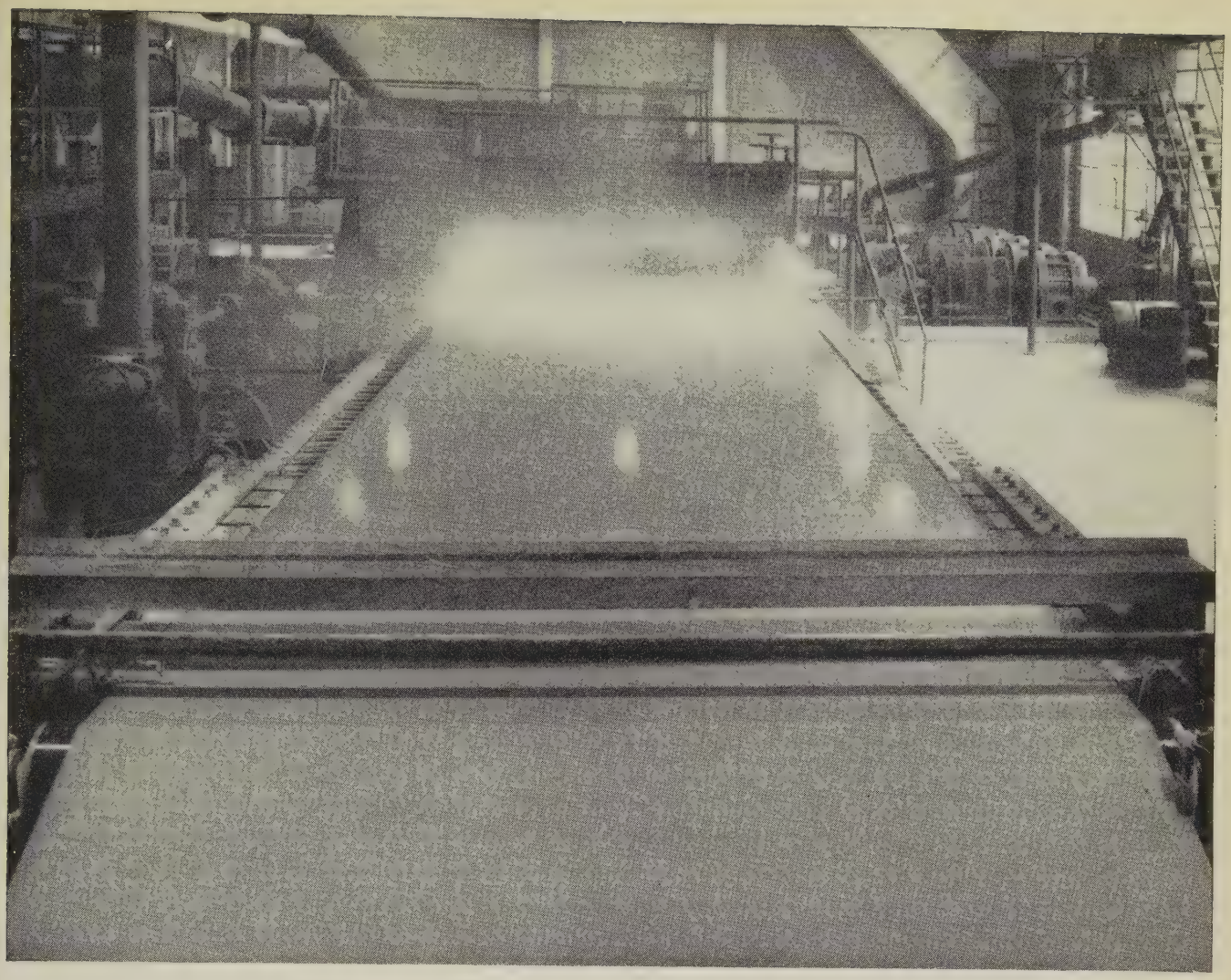
The Executive Committee voted to authorize a local section charter for the St. Louis District of the Chicago Section, provided that this action is approved by the Local Sections Operations Committee.

Paper Progress Award

J. R. Lientz presented a request from the Corn Products Co. to provide an annual "Paper Progress Award" to be awarded by TAPPI to that representative of a paper manufacturing firm who contributes to the technical progress of the industry.

After considerable discussion the Executive Committee concluded that any such award might detract from the significance of the TAPPI Medal. Accordingly J. R. Lientz was asked to advise the Corn Products Co. that its kind offer had been declined.

At 6:10 p.m. the meeting was adjourned.



A Complete Starch Line... *tailor-made to your needs*

Today's complex papermaking operations require a wide range of starches—starches specifically designed to do a particular job. You'll find that the complete starch line offered by Corn Products Company includes types for every phase of modern papermaking. These starches are available in so many varieties that *they can literally be tailor-made to suit individual requirements* and production problems of individual plants!

For example, in beater sizing, preferred starches for improved surface qualities plus excellent bursting and tensile strength, include the many varieties of Globe and pre-cooked Amijel. For calendar sizing, you'll find a complete line of Claro and Eagle starches, as well as Globe starches for enzyme conversion. In this operation, Globe and Excello dextrines and thin-boiling Foxhead starches are also used. For general coating, with good viscosity at high solids content, use Claro and new improved Ten-O-Film starches.

And the research staff of Corn Products Company, largest in the industry, is constantly at work developing new products to meet the changing needs of modern papermaking.

Our technical representatives are completely versed in the problems that arise with wet end additives. Their impressive field experience and continuing research into starch, evidenced by frequent publications in trade and technical journals*, is always at your service. Take full advantage of the facilities and experience of the world's largest corn processors—call our nearest sales office or write direct.

Fine products for the Paper Industry: GLOBE® • EAGLE® • FOXHEAD® • CLARO® • AMIJEL®
CORAGUM® • TEN-O-FILM® starches • GLOBE® • EXCELLO® • LAM-O-DEX® dextrines and gums.

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Clete Smith, who helped develop a special solvent formulation for flushing rocket fuel tanks, says you'll like doing business with Columbia-Southern

Technical Service Engineer Clete Smith is one of many Columbia-Southern specialists who recently teamed up to formulate a new solvent for cleaning rocket fuel tanks and other parts without damage to the special metals and alloys used in rocket construction.

Aimed at solving a specific customer problem, this product is one example of Columbia-Southern's emphasis on keeping customers' needs foremost. Throughout the company, the aim is to develop products and methods and to work closely with customers to insure the most effective use of Columbia-Southern chemicals—and service.

For example, Technical Service recommendations on vapor degreasing with Columbia-Southern Trichlor recently saved a large chain-saw manufacturer $2,100 in tank maintenance costs in just 22 weeks. And an analysis of a window-frame vapor degreasing set-up, also using Trichlor, resulted in a 30% reduction in solvent consumption.

These are just some of the reasons why so many companies in every industry find it pleasant—and profitable—to do business with Columbia-Southern. They like the extra service Columbia-Southern routinely delivers along with its quality products.

Anhydrous Ammonia, Barium Chemicals, Benzene Hexachloride, Calcium Chloride, Calcium Hypochlorite (Pittchlor®, Pittabs®), Carbon Tetrachloride, Caustic Potash, Caustic Soda, Chlorine, Chlorinated Benzenes, Chloro IPC, Chrome Chemicals, Hydrogen Peroxide, Muriatic Acid, Pacific Crystals, Perchlorethylene, Rubber Pigments (Calcene®, Hi-Sil®, Silene®), Soda Ash, Sodium Bicarbonate, Sodium Sulfate, Titanium Tetrachloride, Trichlorethylene

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Italian TAPPI Receives Charter

On Oct. 6, 1959, at the Villa d'Este, Lake Como, Italy, the Italian Section was presented with a charter by the Technical Association of the Pulp and Paper Industry. More than 90 members and guests of the section were present.

R. G. Macdonald, assistant to the president and Walter C. Bloomquist, member TAPPI Executive Committee, attended the ceremony in behalf of the TAPPI Executive Committee and Mr. Macdonald made the presentation address ("Papermaking Pioneering and TAPPI," *Tappi* 42, No. 10, 12 A–13 A (Oct., 1959)). He also gave the chairman of the Italian Section, Piero Bersano, a banner, charter, and gavel.

Mr. Bersano accepted the charter and spoke about the tasks to be fulfilled by the Italian Section.

The speaker at the meeting was Professor Gustavo Colonnetti, president emeritus of the Consiglio Nazionale delle Richerche.

Mr. Bersano's acceptance remarks follow:

It is with a deep pleasure indeed that I fulfill my high task to open the official ceremony of the Charter Presentation to our Italian Section as a "Local Section of the Technical Association of the Pulp and Paper Industry."

This pleasure is mainly due to the fact that the endeavors of the whole Executive Committee have not really been in vain, as it can be clearly evidenced by your large attendance at today's ceremony, and by your presence too at all the rather lively meetings and discussions we have had up to now.

It can be therefore plainly stated that the formation of a technical section of papermakers is now an imperative necessity so that all doubts and fears which could arise in January, 1958, when a small group of people resolved to start the formation of our present association, are to be considered as fully transient.

Ville d'Este, Lake Como, Italy

At the time we started our activity as an Association of national character we were a group of 30 or more TAPPI members existing then in Italy.

The work carried out in those days amidst a lot of difficulties of every kind allowed us to obtain, in February, 1959, the valued recognition as the Italian Local Section.

No doubt the meaning of such an acknowledgment is fully clear to each of you because of two different considerations, namely that we are joining the great TAPPI family outside all national and regional boundaries of a continent.

In fact, we are joining a family whose members are spread all over the world, who do not speak our same language, but feel very glad to help us overcome many of our technical difficulties.

We have at the same time the great honor to be a group which, for the first time in the TAPPI history, is being officially acknowledged outside the territorial boundaries of the United States. You all have worked and cooperated in

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Piero Bersano, chairman of Italian TAPPI and G. W. Dietrich, executive vice-president, Beloit Italia

order to give the necessary proof of activity so as to obtain such appraisal an acknowledgement. I feel sure that you have done so because you have understood that it is of general interest to us all to bring forth ideas and discuss problems aiming to a greater and greater progress and improvement of the paper industry.

This has been done in fact during the last two years through frequent meetings, the organization of the annual meeting of the TAPPI European Study Group, the formation of various committees such as those of "mechanical pulp," "testing methods," and "beating," which all are working satisfactorily and the results of which are expected to be shown shortly.

All this work complies with the program you can read in the TAPPI Bylaws, but we feel we have started something more which cannot only be of direct interest to us, but can also make us known by others.

At the Bari meeting which was held last month a determination was resolved upon which I think will be of basic importance for the Italian Local Section, namely to thoroughly study all the raw materials which are available here in Italy, the possibilities of using new ones, the processes to be adopted for the exploitation of raw materials being different from the conventional ones, so as to be able to be of assistance to all our members in their efforts to reach the most important aim of our industry, namely to attain an actual improvement in both quality and quantity of the normal production.

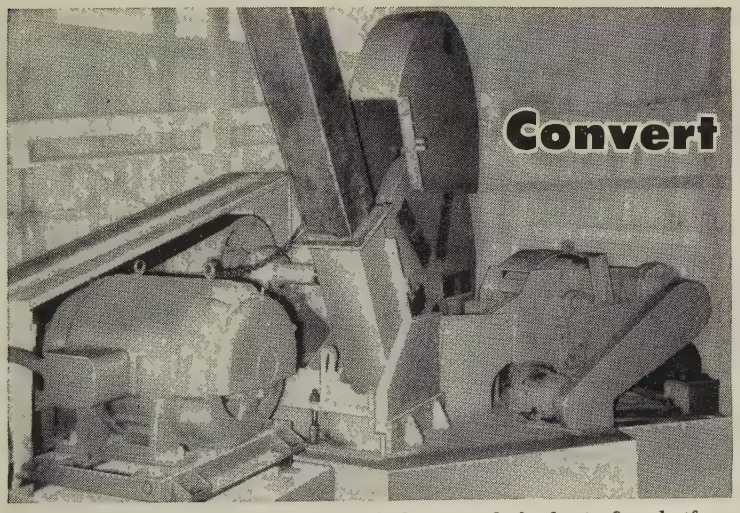
I wish to thank the authorities who kindly accepted to attend this ceremony, and namely

the Como Prefect, His Excellency Giacinto Guida
the USA Ambassador Representative, Charles Moffly
the Past President of the "Consiglio Nazionale delle Ricerche," His Excellency Prof. Gustavo Colonnetti
the President of the "Amministrazione Provinciale" of Como, Aldo Rossi
the President of the Como Chamber of Commerce, Eugenio Rosasco
the President of Como "Unione Industriali," Emilio Sancassani
the Director of Como "Unione Industriali," Achille Baglioni

and, before closing, I would wish our new "Italian Section" a greater and greater success through the harmony of all its members, free discussions and the development of new ideas.

Such a wish is really a very sincere one, as it comes from a person who holds—though undeservedly—this office, but who can state, too in all sincerity of mind that he has always been fighting in order to improve our working conditions with regard both to labor and capital, and who firmly believes that the ingenuity of our Italian people can still develop great and useful activity resulting in further progress and in a possible conveyance to others of important knowledge.

An article on the GEC Exhibition which I noticed in a weekly magazine was entitled: "machines for ideas." Well,



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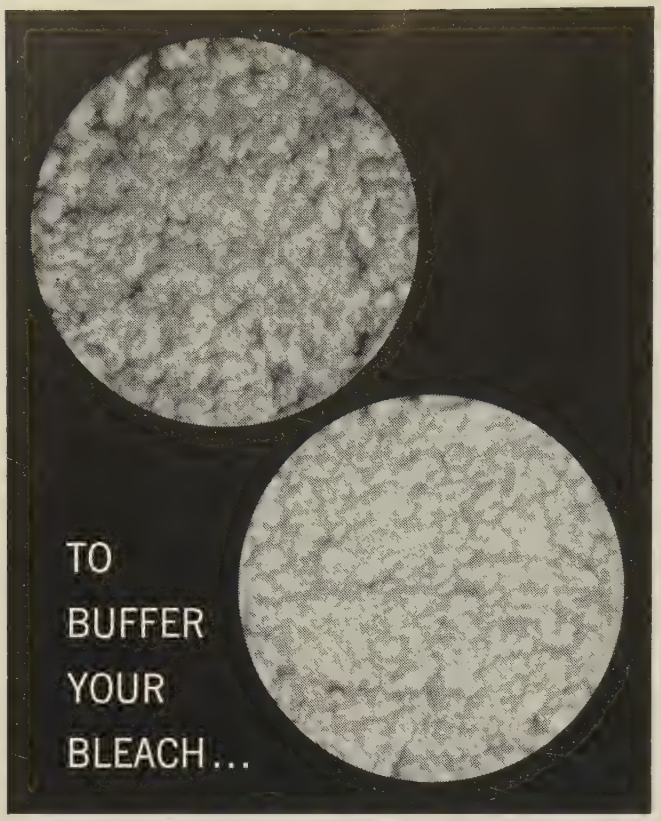

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ideas for machines is just, in my opinion, the highest aim of our association, namely to frame new ideas for machines, processes, etc. so that they can arise in future through friendly meetings among us. If this occurs and such ideas cause our industry to be more and more standing we shall really be able to state that our efforts have not been useless.

This is what I wish our association and all of you.

I wish too to warmly thank His Excellency Professor Gustavo Colonnetti who shed lustre on this meeting, speaking about the "Metrology in the Technique of Both Production and Labor."

Training Technicians for The Italian Paper Industry

Gustavo Colonnetti

IT WAS during my visit to the "Atom for Peace" Exhibition in Geneva that I realized for the first time the importance that could be attached to some modern scientific and technical improvements in your industry. if they are utilized in the most delicate operations of production measurement and checking.

I learned then that the use of the radioisotopes would allow exact and easy checkings of the homogeneity and evenness of the paper sheets coming from your machines, signaling and localizing any defect, however little it may be, and paving the way for any possible endeavor to obviate such faults and perhaps to do so even automatically.

I just recollected this fact when your committee kindly invited me to deliver a speech today before you who are assembled here to celebrate the formation of the Italian Section of the Technical Association of the Pulp and Paper Industry.

This remembrance also suggested me the idea to deal briefly with the problem relating both to units and methods of measurement, which is rapidly gaining in increasing interest for all industries.

I also feel greatly encouraged by the words Mr. Macdonald has just uttered with regard to the present cooperation between universities and American industries, and to the interest these industries are showing for research.

Though I am unqualified and not versed in the secrets of your operations nevertheless I keep in frequent and interesting touch with technical people who in the various industrial concerns have the delicate task to control the production and improve it both from the quality and quantity standpoint.

I often hear these people express some perplexities as to the organization of the above controls, their constant defectiveness, and sometimes too as to basic questions such as the selection itself of measurement units and the exactness of the equipment they have available and which they often find as not fitting the purpose they expect to attain.

If we think in fact that the insufficiency these technicians complain of at present is likely to get more and more serious in the next years—when, because of the advent of the common market the highest degree of quality of our products shall be more and more closely compared with foreign products and the tolerances shall be increasingly reduced by the requirements of a larger and more widespread interchangeability—we are led to realize that nothing could result indeed more profitable to our country, its economy and prestige itself, than a scientific and technical definite progress of the measurement units.

Both the science and technique of measurement units must progress in concert in all fields, from that of the fundamental units of length, mass, and time, up to the one relating to the resistence of materials and their behavior in different room conditions, that is to say when the hygrometric state is varying and highest and lowest temperatures are occurring.

This can be obtained of course through the use of all the resources of modern physics, running from optics to acoustics,

from magnetism and electricity to electronics and radioactivity, as each of these branches of physics can offer, under particular circumstances.

However, the large use of such means which both science and technique of measurements are offering us on an increasingly large and various scale, involves a great and increasing number of experts being available on different levels: from the skilled workman to the shop manager, the industrial expert, up to the engineer. All these people should not only have acquired a sound training at school and laboratory, but they also should keep in continuous touch with both school and laboratory so as to be opportunely informed of all progress occurring in the measurement science and technique. In such a way the progress can immediately reach the production and work field and be consequently utilized.

Scientific and technical progress has strikingly increased lately and we can state that in the course of a few years we have gone as long a way as the one which could be done in past times in the course of many generations.

As a matter of fact we do not live any more in the world where we were born, but in a fully transformed one which goes on varying and evolving under our own eyes and which also compels us to transform ourselves and develop together with it, as otherwise we would suddenly find ourselves obsolete and swept away.

Someone, whose name I do not remember at present, has said that if we do not want progress to burst in our face, we must see to it that the time elapsing between discovery and its technical application, between what is known only by a few people and what represent the cultural patrimony of the whole mankind should be minimized.

Of course, it is a question here of a quite new task which must be faced by school in the interest both of the country and industry; but not by the present time school, which would not be able to fulfill such a task owing to its being restricted to very noble but unfortunate tradition. A new school is therefore needed which should be renovated *ab imis* and made sensitive to our present time requirements.

It is your duty, however, in your capacity of exponents of industry who are aware of the problems concerned, to ask the school and competent authorities for such a sound renewal of conventional methods and structure.

The duty of the school can no more be considered as fulfilled as it was in past times, by providing for the conveyance to the new generation that knowledge of methods and techniques representing the cultural patrimony of the preceding generation.

Nowadays, methods and techniques are getting old and because obsolete in the course of a few years, and they even threaten to become a depreciated patrimony and a useless intellectual store should they not be properly integrated and renovated.

School must now develop for young people a first formative period designed to enable them to most reasonably and consciously face their future tasks.

Yet, this training period which is required for practising a profession or a trade cannot claim to deal with all subjects or to go beyond what is strictly necessary; and neither can it regard itself as achieved through a degree, the more or less solemn bestowal of which often shows a definite separation between the study life and the work one.

It is imperative, on the contrary, that the transmission of knowledge should continue to reach the scholar, the technician, and the professional man, that is to say, in a word, the man who works wanting at the same time to adjust his work to increasingly new requirements and to get new acquisitions of science which he will avail himself of, as integrating and improving means for his industry, and an instrument of social progress.

Therefore, we shall never sufficiently deplore the trend of certain academic circles to extend indefinitely the school program and to establish more and more courses, thus in-

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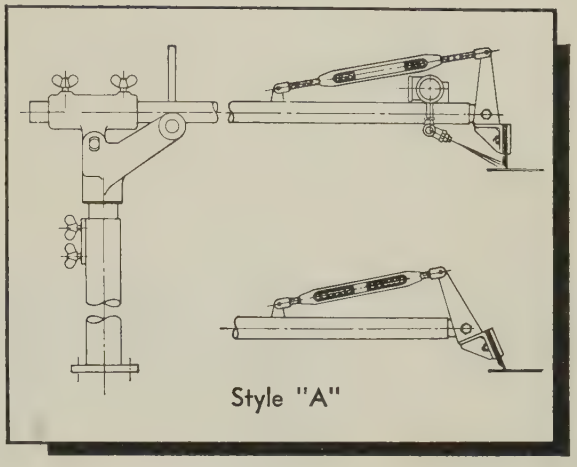

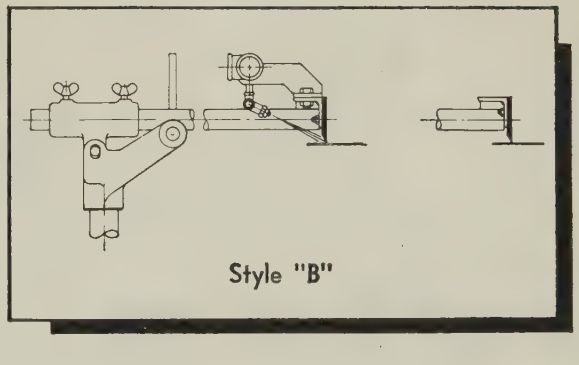

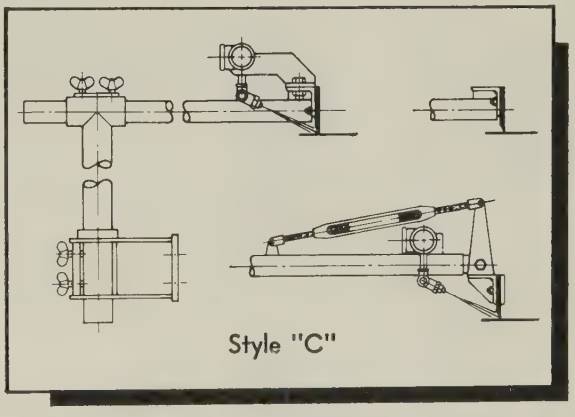

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creasing the burden and extending the duration of studies, in the vain endeavor to improve the school efficiency and to increase the rather uncertain value of the degrees, conferred by the school itself.

It is necessary for young people to get in touch as soon as possible with the production and the work world where problems are put forward and must be solved.

On their facing these problems young people must realize what they have still to learn and convince themselves of the necessity for them to keep studying not for one or two years longer, as students, but for their whole life long as workmen or professional men.

In such a way they will feel the want of exacting from school to be supplied with the possibilities of being acquainted with the latest progress, both technical and scientific, in the ways and trends which can allow them to work better and to produce more.

It is for you, however—as you are certainly aware of the agreement existing between these longings of the studious young people and the requirements of your industry—to pave the way for young people, by requiring of the academic spheres and authorities concerned a sound renewal and a different school structure, together with new and more elastic plans of study and work which may better meet the progress and development requirements of your industry.

We shall try therefore to obtain from schools a proper training and assistance through teaching and control methods far different from the conventional *ex cathedra* lessons and examinations now worrying our university life.

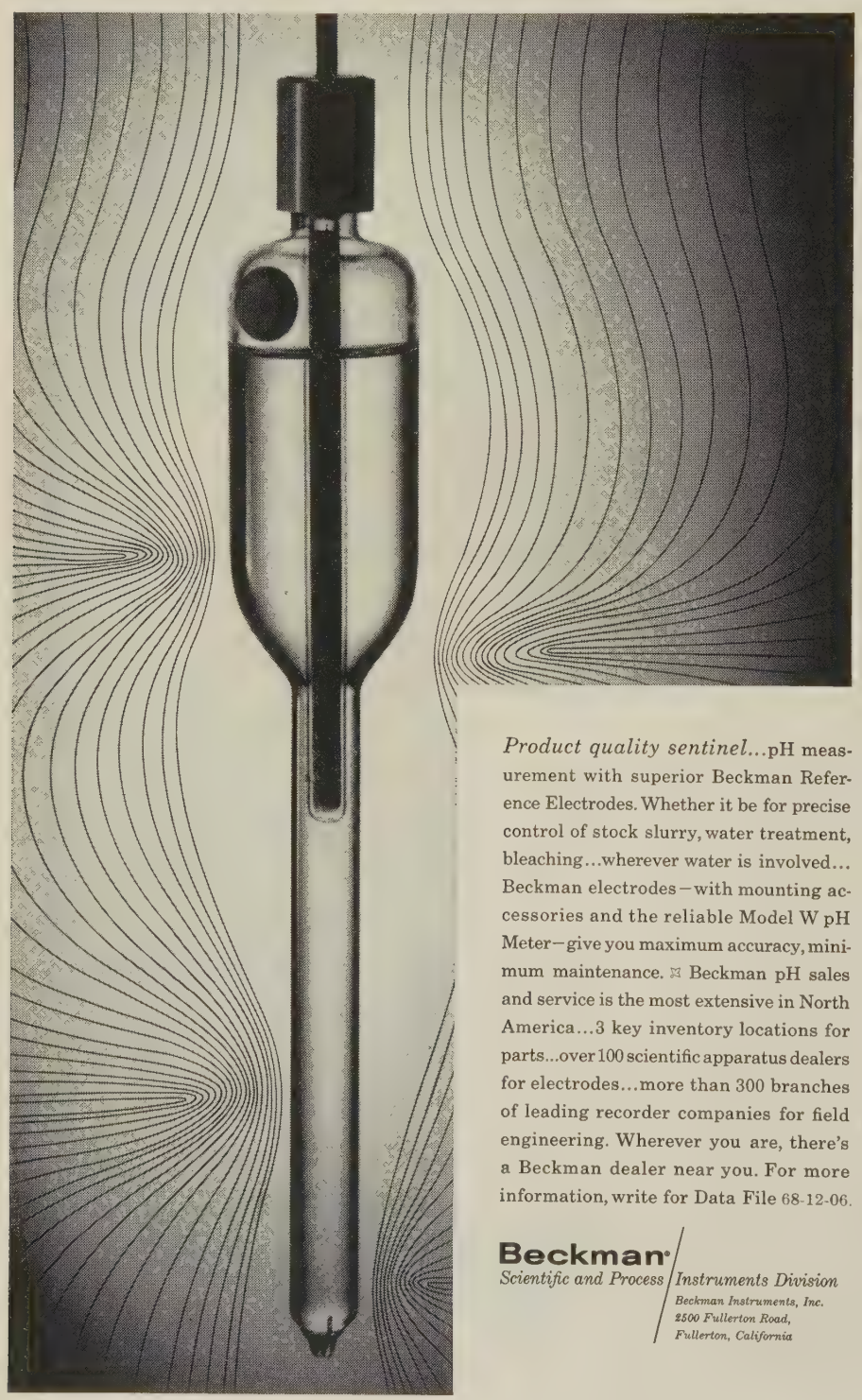
It is with a great appreciation indeed of the nice opportunity I was offered, and in my capacity of an old teacher of the engineering faculty to discuss with you all the aforegoing problems.

I would like in fact now that events are really pressing, our country not to be left behind in the noble challenge in which the mightiest and most advanced countries are contending for supremacy.

Through the useful and constant effort the modern man is now making to increase beyond all limits his knowledge, to master the whole world by his genius and to submit the natural forces to his own will, a new civilization of science and techniques is really arising.

So it is imperative for our nation, based on a military and humanistic tradition, to engage its whole will power and natural ingenuity and work capacity to shape the face of this new civilization, to address it toward peaceful aims and to impress on it a human character so as to render it an instrument of man loftiness.

I feel that associations like yours can valuably contribute to the attainment of such an aim, the validity of such contribution increasing in proportion to the open mindedness with which you are prepared to face the peculiar problems.



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European Ramblings

The following is a brief report by R. G. Macdonald, Editorial Director of *Tappi*, about his recent trip to Europe.

The trip was a busman's holiday in that while there was much scenery and places that any tourists usually see there was a frequency of technical meetings quite similar to the pattern in the United States.

The jet trip to Paris and Milano was made in company with Don Macaulay, at one time with S. D. Warren Co. Mr. Macaulay has earned an excellent reputation as an exponent of the application of statistical quality control. He was on his way to conduct a seminar on this subject and market research in Milano and Torino. Later, I understand that he will do the same in Japan.

The principal object of the writer's trip was to attend a meeting at Lake Como, Italy, to present a charter to the new TAPPI Italian Section in behalf of

President Lientz of the Technical Association of the Pulp and Paper Industry. A complete report of this meeting appears elsewhere in *Tappi*.

Several mills were visited. These included the mills of Vita Mayer & Co. with its new and excellent semichemical pulp mill and new tissue mill; the Milano and Conca Fallata mills of Cartiere Ambrogio Binda where fine papers and coated papers (S. D. Warren process) were made; the Corsico mill of Cartiere Burgo where mechanical pulp and groundwood papers were made. At the Corsico mill the writer had an opportunity to see the new wood grinder developed by Piero Bersano and described earlier at the TAPPI Mechanical Pulping Conference in Quebec.

Another mill of considerable interest was located near Trieste, the Cartiere di Timavo. It was very new, making newsprint on a machine made by Valmet Oy of Finland. Mr. Pesonen and some of his papermakers came from Finland to operate the mill.

While in Rome an opportunity was provided to see the mills of Tiburtinee Industrie Affini at Tivoli. Here the local abundance of water from the surrounding mountains were made manifest, not only by the Tivoli Gardens with its 1400 fountains but also by the groundwood mill furnishing its product by means of cable baskets to the mill located in an ancient castle at a very great height above the grinder building (at least the equivalent of a 25 to 30 story office building). The small associated mill located on the town level in Tivoli was typical of many mills in Italy, consisting of a pug mill to reduce old papers to nodulized pulp, running the product through a kollargang, and forming a product such as press board on a wet machine and an hydraulic press. The product looked good although the daily production was very little.

Aside from the Italian paper mills, the writer had an opportunity to visit the Beloit Italia plant at Pinerola, near Torino. This plant which formerly repaired and rebuilt railroad cars is now owned by Cartiere Burgo and the Beloit Iron Works. George Dietrich, the vice-president and general manager, has converted it into a modern and efficient paper machinery building operation.

While in Milano several representatives of American paper companies were observed attending the International Show and Congress of Printing, Publishing, and Paper Industries. The writer had attended a similar show at the New York Coliseum the previous week and was impressed with extremely large and functional facilities at the Milano Fair Grounds. Such facilities appear in several European cities, such as Torino and Paris. They are ultra-modern in appearance.

In Rome a visit to Dr. Pastina and the laboratories and the forest experimental station of Ente Nazionale per la Cellulosa e per la Carta were of consuming interest. In Rome there is an exceptionally well equipped pilot plant for the pulping of wood and the preparation of paper. In addition, there is a large warehouse and railroad siding for handling rolls of newsprint. These are commercial rolls obtained from many newsprint companies and held for shipment to newspaper publishers. The forest experiment station is located outside of Rome and is devoted largely, at present, to the growing of aspen and eucalyptus. Many of the rows of poplar trees had their origin in Pennsylvania, Missouri, Mississippi, and other states and are so marked. Their growth is being studied and eventually many of these trees will go through the Rome Laboratories for pilot plant scale pulping, processing, and evaluation.

Following his stay in Rome the writer proceeded to Vienna and Graz in Austria. In Graz opportunity was provided to visit the mills of Arland Papier und Zellstoff-fabriken at Graz-Andritz (sulphite pulp and paper); Leykam-Jofefsthal A.G. at Gratkorn (seven machines, sulphite pulp and paper); and Carl Schweitzer Papierfabrik at Frohnleiten (two machines for newsprint and supercalendered papers). The Arland mill is the headquarters of Professor Ferdinand Wultsch of The

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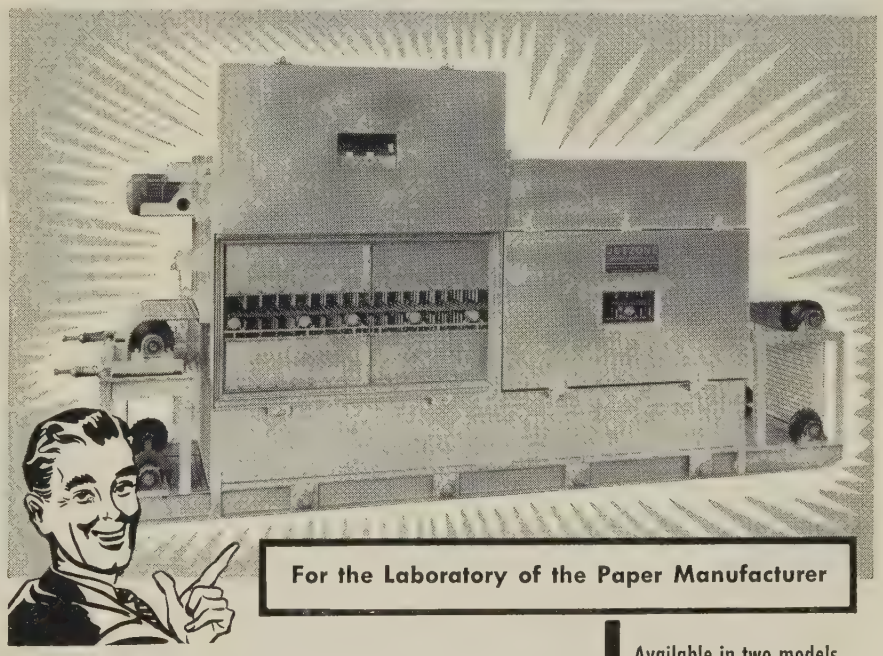

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Technische Hochschule at Graz. Professor Karl Adamic maintains his office at the school. This is the principal pulp and paper university in Austria.

In Vienna an opportunity arose which made it possible for the writer to attend a meeting of Austrian Association of Pulp and Paper Chemists and Technologists. The meeting was held at the Holzforschunginstitut. Two technical papers were presented: "Experience in Planning and Construction of Power Centrals for the Pulp and Paper Industry," by Kurt Fichtner, a consultant from Stuttgart, Germany, and "High Yield Pulping by the Sulphite Process," by Hildegard Nitsch of The Forest Research Institute in Vienna. The meeting began at 4 o'clock and ended at 8, following which there was a social hour and dinner at a nice Vienna restaurant. The writer was the guest of Baron Rudolph Rossler, the secretary of the association.

The next stop was Paris where the third symposium of Eu-Ce Pa was held on October 26 to 29 at the Hotel des Ingenieurs Arts et Metiers, in other words, the very fine Engineer's Club of Paris. The subject of the symposium was "Printability of Paper," Twenty papers were presented and discussed in English, French, and German. Following the symposium an opportunity was provided to visit any of four large and modern printing plants.

Technical Operations Committee

A meeting of the Technical Operations Committee was held at Pittsburgh Airport Oct. 15, 1959, with the following attendance:

P. E. Nethercut, TAPPI
C. E. Brandon, Testing
R. C. Masterman, Paper & Board Manufacture
B. Mendlin, Corrugated Containers
M. J. Osborne, Engineering
R. C. Sturken, Converting & Consuming
R. T. Trelfa, Coating & Graphic Arts
H. O. Teeple, TAPPI
A. J. Winchester, TAPPI

J. R. Lientz, TAPPI president, visited the meeting briefly.

1. P. E. Nethercut reviewed recent actions of interest to Technical Operations Committee members:

a. *Research Policy.* The president's committee on research policy had reported to the Executive Committee, and a revised research policy had been adopted. High lights of the policy are: no sharp changes from existing policy; continuing emphasis on help to committees for short-term work connected with committee projects; funds to be taken from company members' dues; name of Research Appropriations Committee changed to Project Appropriation Committee; a research advisory council is to be set up to study whether we should have a truly long-range research program, financed from outside the association; closer control of projects by committees was urged; patent policy remains the same, viz., avoid difficulty by publishing results promptly; $12,000 additional was appropriated for 1959, making a total for the year of $62,000.

b. *Staff Increase.* Approval was given for employing an additional technical man at headquarters.

c. *Division and Committee Changes.* A. J. Winchester reported that, following Technical Operations Committee approval, the president had reassigned the committees of the former Industrial Division to other divisions as follows:

Committee	*Division*
Agricultural Fibers	Pulp Manufacture
Structural Fibrous Materials	Paper & Board Manufacture
Training & Education	Research & Development
Water	Paper & Board Manufacture

There is thus no longer an Industrial Division. The name of the former Paper Manufacture Division has been changed to Paper & Board Manufacture Division.

Some discussion also took place concerning possible changes

involving the Water, Sanitary Engineering, Acid Pulping and Semichemical Pulping Committees.

d. *Headquarters Operations.* P. E. Nethercut reported that an assistant editor had been hired for *Tappi,* that headquarters was about to move to larger quarters at 360 Lexington Ave., and that a monthly newsletter was being planned to keep division, committee, and section officers up to date on association activities.

e. *Career Guidance.* A. J. Winchester reported that the brochure requested by the Technical Operations Committee was almost ready to go to press. A total of $17,000 had been authorized by the Executive Committee for a printing of 50,000 copies.

An inter-association career guidance committee, with representatives from TAPPI, APPA, and PIMA, had recently been set up, with the objective of coordinating all career guidance activities for the industry. H. O. Ware and A. J. Winchester are the TAPPI representatives on this committee.

P. E. Nethercut reported that the program of providing speakers to student chapters is continuing.

Another career guidance activity is the preparation of a workbook of chemical engineering problems being prepared by the Chemical Engineering Committee for use in colleges and universities.

f. *Certificates of Appreciation* have been given to retiring chairman during 1959. P. Nethercut pointed out that they are also available for members who have rendered outstanding service to the association. Nominations for such awards should be sent to headquarters for approval and transmittal to the president's awards committee.

2. The minutes of the Feb. 25, 1959, meeting were reviewed. It was noted that the Engineering Division now has a section in *Tappi* under its own masthead.

3. Project Numbering. It was suggested that better control over committee projects might be attained if different blocks of numbers were allotted to the different divisions. The headquarters staff will look into this and make a recommendation to the Technical Operations Committee by letter prior to the next meeting.

4. Corrugated Containers Reference File. Burt Mendlin reported that the Corrugated Containers Division had resolved to ensure publication of all worthwhile material by making sure it is included in its programs at the Annual Meeting and the Corrugated Containers Conference. They also requested that headquarters duplicate the papers presented at their meetings and send them to all attendees.

5. Preprinting of Papers. Several Technical Operations Committee members expressed a desire to have preprints available at conferences. Mr. Trelfa suggested that preprints of all papers should be available to attendees, and perhaps also for others who may wish to buy them. Such preprints, however, would not be for publication in *Tappi,* but rather the authors would submit special manuscripts in form for publication. After final decision by the Editorial Board as to whether a paper is scheduled for the Technical or General Section of *Tappi,* the author should be advised, and should be permitted to withdraw his manuscript if he so desires.

M. J. Osborne asked if it would be feasible to divide *Tappi* into sections according to the sponsoring technical divisions. It was felt that this would be very difficult, but that dividing the table of contents might be feasible.

Papers presented at the 1960 Annual Meeting Corrugated Containers Sessions will be duplicated and sold. An order form will be available at the meeting for this purpose. Price to nonmembers will be higher than to members.

6. Scope and Authority of Technical Operations Committee. A discussion was held concerning the definition of scope and authority of the Technical Operations Committee. Some members felt that the committee lacked well-defined limits of authority concomitant with its responsibility as given in the constitution. President Lientz, who was present during part of this discussion, stated that the purpose in setting up the

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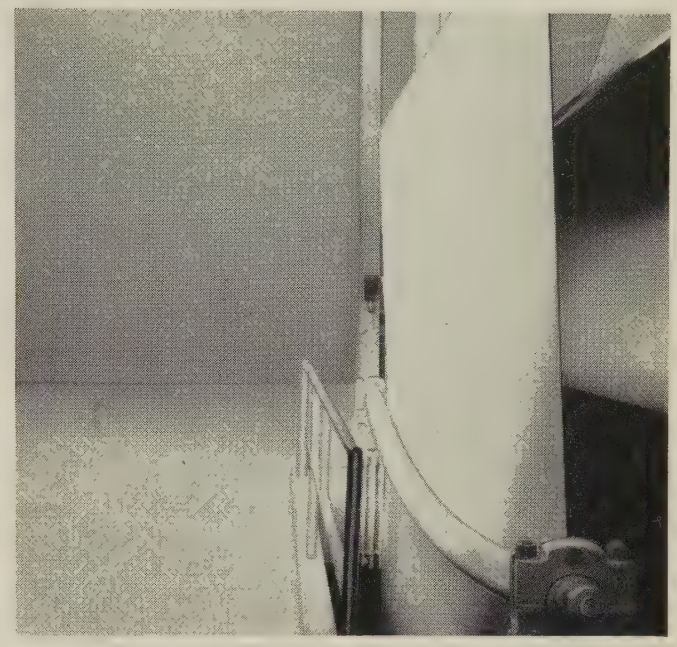

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Technical Operations and Local Sections Operations Committees had been to relieve the Executive Committee of the executive function so that it would become a policy-making body only.

This subject will be discussed further at the February, 1960, meeting.

7. Annual Meeting—1960

The following schedule of meetings was agreed to:

1. Joint advisory
2. Executive Committee
3. Technical Operations Committee breakfast 7:00 a.m. Monday (for communicating Executive Committee decisions only)
4. Division officers' meetings
5. Committee meetings
6. Technical Operations Committee Meeting—Thursday, 9 a.m. to Noon.

The annual meeting is expected to be housed entirely in the Commodore Hotel. Evaluation forms for individual papers and for sessions will be available. The session form will be sent to division chairmen soon for comment.

8. Functional Conferences.

a. It was pointed out that H. O. Teeple and A. J. Winchester are now acting as treasurers for several conferences, and can do so for others if requested.

b. Headquarters can have slides made for authors. This service will be publicized.

c. More headquarters help on local arrangements would be desirable. This was deemed feasible, provided good check lists are used. Headquarters will send a form check list to division chairmen.

d. It was the consensus that conferences are being improved, and that further improvements could result by providing the following: (1.) preprints, (2.) increased headquarters help on local arrangements, (3.) conference evaluation forms. (a suggested form will be sent to Technical Operations Committee before the February meeting.)

e. J. A. Winchester described the public relations program carried on by Fuller, Miele Associates for the 1959 functional conferences, comprising town-of-residence news releases for all authors, plus releases at conference location. Burt Mendlin suggested offering complimentary registration to students and professors in the conference area. The Technical Operations Committee felt that all efforts of this sort are valuable, and as much as feasible should be done.

f. A discussion was held concerning the financing of cocktail parties. Several members favored selling banquet tickets separately from registration and including the cost of the cocktail hour in the banquet ticket.

9. Transfer of Records. Mr. Sturken had asked what could be done to see that new chairman receive files of their committee or division for orientation purposes. Mr. Nethercut stated that if a chairman fails to receive files from his predecessor, headquarters can make copies from their files on request. It was also suggested that incoming division chairmen should attend the Technical Operations Committee meeting.

A. J. WINCHESTER, Secretary

Fourteenth Plastics-Paper Conference

The Fourteenth TAPPI Plastics-Paper Conference was held at the Edgewater Beach Hotel, Chicago, Ill., Sept. 20–23, 1959. A total registration of 467 made this by far the largest Plastics-Paper Conference to date.

The Plastics-Paper Conference is sponsored by the TAPPI Converting and Consuming Division, R. C. Sturken, Frank W. Egan Co., Somerville, N. J., general chairman.

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The committee responsible for the 1959 conference was as follows:

Chairman: W. L. Hardy, International Minerals & Chemicals Corp., Skokie, Ill.
Program: G. H. Sullivan, H. P. Smith Paper Co., Chicago, Ill.; C. C. Sutton, General Foods Corp., Tarrytown, N. Y.; J. V Eller, H. P. Smith Paper Co., Chicago, Ill.; C. M. Fields, Continental Can Co., Mt. Vernon, Ohio; W. B. Tibbets, Union Carbide Plastics Co., Bound Brook, N. J.; H. A. Spencer, Knowlton Bros., Watertown, N. Y.
Local Arrangements: W. R. Price, Central Waxed Paper Co., Chicago, Ill.; R. Weber, Paperboard Packaging, Chicago, Ill.; H. L. Vallandigham, Great Lakes Carbon Co., Chicago, Ill.

The conference included five technical sessions, an official banquet, and meetings of the Plastics Committee and Plastics Laminates Committee of TAPPI. Brief summaires of the papers presented are given below. The full text of all papers will appear in future issues of *Tappi.*

A high light of the conference was a panel discussion on: The Food and Drug Administration Rulings and the Obligations of Industry. The full text of the presentations given by this panel appears in the November issue of *Tappi.*

First Session

The opening session of the conference was held on Monday morning, September 21 under the chairmanship of C. C. Sutton, General Foods Corp., Tarrytown, N. Y. After opening remarks by R. C. Sturken, general chairman of the sponsoring Converting and Consuming Division, Mr. Sutton introduced V. T. Stannett, College of Forestry, Syracuse, N. Y., who presented a "Final Report on the Mechanism of Gas Transmission Through Permeable Membranes," and also a "Summary Report on the Mechanism of Water Vapor Transmission Through Permeable Membranes." Both reports concerned work carried out at Syracuse under TAPPI Research Appropriations.

Mr. Stannett discussed work carried out under TAPPI sponsorship on the gas and water vapor permeability of plastics and plastic coated papers.

The accepted modern theory of permeability was presented and slides shown of the equipment used at the State Forestry College at Syracuse, N. Y. The following areas of research were presented.

1. The effect of one gas on the permeability of another including the effect of relative humidity on gas transmission.
2. The effect of the paper layer on the barrier properties.
3. Effect of the crystallinity of, e.g., polyethylene and polypropylene on gas transmission.
4. The barrier properties of some grafted polyethylenes made by high energy radiation were presented.

New work was presented on water vapor permeability using radioactive water (Tritium-containing water) showing the extremely low water sorption of polyethylene, less than 0.003% by weight.

"*The Effect of Resin Properties on Extrudability in Paper Coating and Properties of the Coated Paper*" was the next paper of the opening session, by John F. Morris, Spencer Chemical Co., Kansas City, Mo. Papers are coated commercially to improve the surface quality, to protect products to be packaged, and to facilitate sealing in the packaging operation. The work covered by Mr. Morris was a statistically designed experiment aimed at quantitatively determining what properties of polyethylene contribute to the ease of extrusion and desirable properties in the finished product.

Extrusion. It was found that a decrease in melt index increased the viscosity, made the resin more difficult to draw

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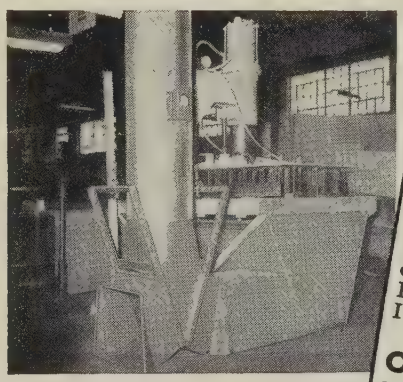

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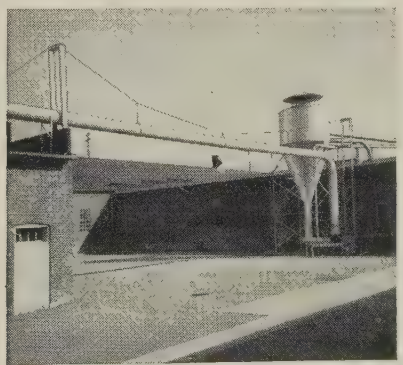

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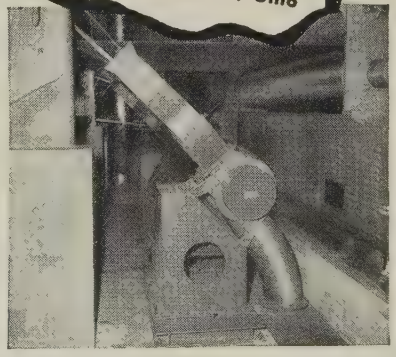

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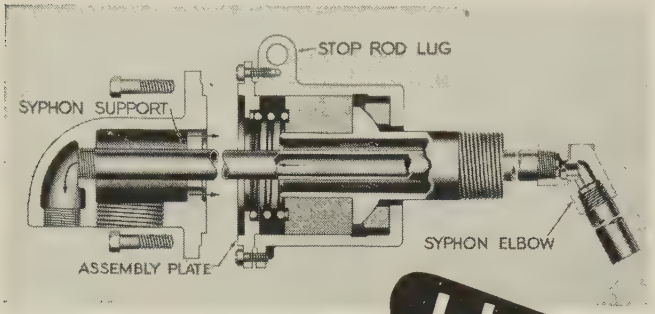

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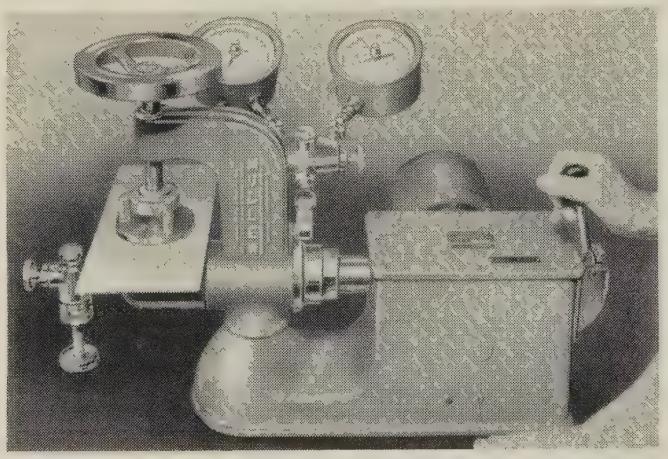

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Fourteen Plastics-Paper Conference Committee: seated: G. H. Sullivan, W. L. Hardy, W. R. Price; standing—J. V. Eller, H. A. Spencer, C. C. Sutton, R. Weber, and H. L. Vallandigham

to thin gages, and improved the neck-in properties. A narrowing of the polyethylene molecular weight distribution had the effect of making the extrusion more difficult through a high shear die, the smoking decreased and the odor level decreased. An increase in polyethylene density caused the neck-in to increase; the viscosity also increased which caused an increase in power consumption.

Coating Properties. The advantages of using a medium density polyethylene resin are that the increased stiffness, tensile strength temperature resistance, surface hardness, abrasion resistance contribute to improved machinability in converting. The improvement in impermeability to gases, liquids, and greases is an advantage in packaging.

The disadvantages of higher densities are less resistance to heat aging, lower production rates, and higher power consumption.

Even though the resin costs in the medium density range are somewhat higher, it is less costly to use these resins if the purpose of coating is to retard permeation.

If the polyethylene is being used as an adhesive, to upgrade the paper product, or to provide a heat sealable surface, it is more advantageous to use a lower density polyethylene resin.

"Proper Marriage of Paper to Plastics and Foils," by Yale M. Brandt, Reynolds Metal Co., Richmond, Va., was the next paper. Mr. Brandt stated that the use of glassine-foil-polyethylene combinations for flexible packaging is increasing. Reverse printing of transparent glassines overcomes many of the problems encountered with inks and coatings on the outside surface. Urea sodium nitrate plasticizers adversely affect the rotogravure applied nitrocellulose inks. Urea-glycol and urea-glycol-sugar plasticized papers are found to give satisfactory ink adhesion. Primer coatings, such as shellac, will also promote ink adhesion. Mr. Brandt described a simple procedure for laboratory testing.

Final paper of the Monday morning session was, *"Polyethylene Films versus Polyethylene Paper Combinations: A Comparison in Relation to Automatic Food Packaging,"* by D. G. MacDonald and M. L. Downs, Thilmany Pulp & Paper Co., Kaukauna, Wis. Mr. Downs, who presented the paper, showed data comparing the protective and mechanical properties of unsupported polyethylene film and various combinations of polyethylene paper, foil, and wax. The data included the permeability rates of nitrogen, vegetable shortening, and moisture vapor and also stress-strain relationships. The authors concluded that although unsupported film is desirable from a cost standpoint in the intermediate protective range, paper-polyethylene combinations offer advantages in mechanical properties for automatic packaging machine operations. Combinations including foil are necessary for maximum protection as needed.

First Session: C. C. Sutton, General Foods Corp.; V. T. Stannett, State University College of Forestry; J. F. Morris, Spencer Chemical Co.; Y. M. Brandt, Reynolds Metal Co.; and M. L. Downs, Thilmany Pulp Paper Co.

Converting Session

On Monday afternoon, September 21, J. V. Eller, H. P. Smith Paper Co., Chicago, Ill., acted as moderator of a panel discussion on the present and future for various plastics-paper combinations. The text of the panel members' presentations is given in full elsewhere in this issue of *Tappi*.

Production Session

C. M. Fields, Continental Can Co., Mt. Vernon, Ohio, was chairman of a Production Session on Tuesday morning, September 22. *"Problem of Odor in Polyethylene Coated Structures,"* by H. Strome, Continental Can Co., Mt. Vernon, Ohio, was the first paper of the session. Odor in extrusion coated polyethylene must be controlled if polyethylene coated products are to enjoy a continuing growth in food packaging, Mr. Strome stated. A partial responsibility for this control lies with the resin supplier, but the major effort must come from the converter; for it has been demonstrated that heat damage in extrusion is the principle cause of objectionable odor.

Infrared spectrophotometry has shown that carbonyl containing compounds are formed by chemical reactions initiated when polyethylene is exposed to high extrusion temperatures for appreciable periods of time. Carbonyl concentration appears to be directly proportional to the odor level, and both are increased markedly by accelerated aging of the heat damaged films. Polyethylene films which have not been severely heat damaged do not develop objectionable odor, nor is there a detectable concentration of carbonyl containing compounds, even after accelerated aging.

From this it might be concluded that the converter need only to reduce extrusion temperatures to avoid odor, but, unfortunately a degree of heat damage is generally required to obtain bond to the substrate. Therefore, the converter must be watchful of his extrusion conditions and apply realistic quality control tests that will predict possible odor development as his product ages.

E. H. Myers, Monsanto Chemical Co., Springfield, Mass., presented the second paper of the production session, *"Polyethylene Film in the Extrusion Coating Market."* After reviewing the history of the process, Mr. Myers presented a market research study of polyethylene extrusion coating as used to produce a "single" web possessing the superior properties of each component material. A study of markets indicates the largest growth in the coating of paperboard. The largest single current end-use market is in multiwall shipping sacks. New potential high-growth markets are containers for milk and other dairy products, corrugated and

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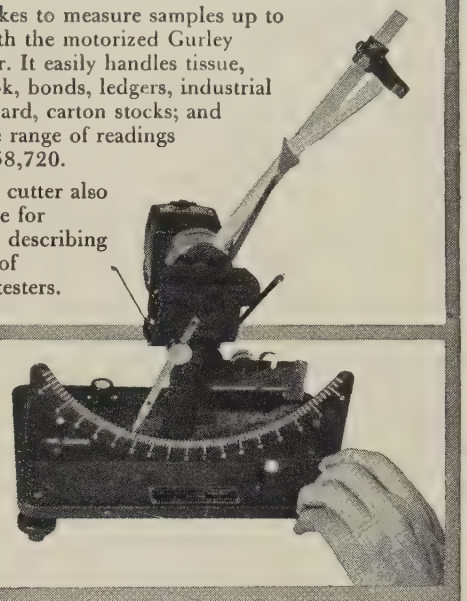

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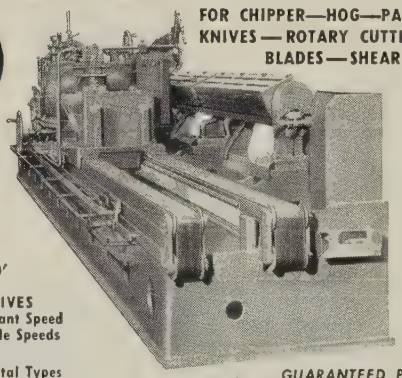

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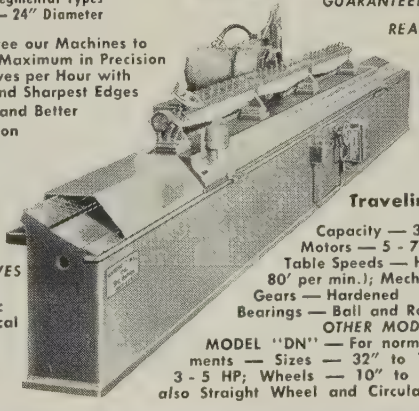

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solid fiber shipping containers, frozen food packaging and fresh meat packaging. A major factor affecting the future growth of the industry is the development of a fast-acting, long shelf-life adhesive.

"The Interaction of Processing Variables, Base Materials and Resins in Polyethylene Extrusion Coating" was the next paper by J. P. Goslin and H. F. Sweeney, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del. Mr. Sweeney, who presented the paper, commented that many processors in the extrusion coating industry use one or two base materials and a single resin. With broadening markets, there is a concurrent demand for wider product selection. Coaters are becoming familiar with a greater variety of substrates and resins, and more detailed performance information would be helpful in using these materials.

Mr. Sweeney described the effects of processing variables on the adhesion and heat seal properties of six polyethylene resins coated to each of five base materials: kraft paper, MSAD-80 and K type cellophane, "Mylar"® and aluminum foil. Resins of widely different melt index and density illustrate how these parameters influence finished product quality. The processing variables studied include melt temperature and gage. Their effects on adhesion and their variations among resins and substrates are described. Heat-sealing strength trends demonstrate the important role of the base material, and the complex relationships of variables.

The fourth paper of the Tuesday morning session was *"Flexible Packaging Material Factors in Automatic Packaging,"* by F. J. Sloan, Packaging Consultant, Springfield, Mass. Whether it is a sheet of cellophane, paper, paper plastics combination or straight resin extrusion film, said Mr. Sloan, they all have one thing in common, on automatic packaging equipment, they must all successfully run. In the course of normal trial and error methods of determining whether or not a given piece of flexible packaging material will operate under production conditions on automatic packaging equipment certain bits of knowledge are learned. This knowledge is not always learned systematically but rather on a practical day-to-day basis.

In attempting to analyze cut-to-size and self-measuring wrapping machines and form fill bag machines for operational factors we must primarily keep all three types of machines in mind simultaneously. In doing so we arrive at a break down of six component considerations.

These components can be subdivided into 34 factors. This is a high light study of the interrelationship of these factors and trouble points and the interchangeability in use of packaging materials.

Converting Session: J. V. Eller, H. P. Smith Paper Co.; M. W. Kane, The KVP Co.; R. H. Mosher, Kimberly-Clark Corp.; G. Hungerford, Kordite Corp.; and H. Schwappach, Minnesota Mining & Manufacturing Co.

Production Session: C. M. Fields and T. H. Strome, Continental Can Co.; E. H. Meyers, Monsanto Chemical Co.; H. F. Sweeney and J. P. Goslin, E. I. du Pont de Nemours & Co.; F. J. Sloan, consultant; and A. J. Ward, Jr., and W. J. G. McCulloch, Enjay Laboratories

The interrelationship is increasingly more important to the machine designer as packaging machines speed increase.

There are about 15 factors that, if controlled, would relieve the packaging line operator of responsibility for the final successful operation of the packaging materials. The aim of this listing of factors is to point out the fact that they do exist and can be analyzed in advance.

It is only logical that all of these details, from the technical angle, should be worked out and full interlocking information be available within the suppliers themselves. This would allow the packaging line operators to spend their time and energies on the basic things of their manufacture.

To accomplish this required considerable inter-industry cooperation and time.

"Extrusion Coating of Polypropylene on Paper," by W. J. G. McCulloch and A. J. Ward, Jr., Enjay Laboratories, Linden, N. J., was the final paper of the production session, presented by Mr. McCulloch. The unique combination of strength, barrier, and thermal properties of polypropylene coupled with attractive finished appearance make polypropylene a strong candidate in the extrusion coating field. Mr. McCulloch summarized these properties and compared them to those of the more conventional coating resins. He then discussed the effect of design and operating variables and of resin properties on the melt drawdown of polypropylene, and showed that die design, die position, and chill roll temperature markedly affect drawdown. As anticipated, resin properties also have an appreciable effect. Encouraging processing rates of 160 f.p.m. have been obtained on laboratory equipment at coating thicknesses of $1^1/_2$ mils and under. For optimum coatings, the authors recommended that Escon polypropylene of high density and high melt index be used and that this material be processed in extruders of large L/D ratio, equipped with a coat hanger-type die. Further, the die should be positioned properly over the rubber roll, with the chill roll operated at relatively high temperatures.

Plastic Laminates Session

On Wednesday morning, September 23, a Plastics Laminates session was held under the chairmanship of H. A. Spencer, Knowlton Bros., Watertown, N. Y. Mr. Spencer is chairman of the TAPPI Plastics Laminates Committee. The first paper, *"Effect of Volatile and Moisture Content on Electrical Properties of Phenolic Resin Paper Laminates,"* by Myer Ezrin and Stuart H. Rider, was presented by Mr. Ezrin, who stated that studies of the effect of volatile and moisture content on electrical properties of paper laminates had been conducted using a cresol resin and an aniline mod-

General Session: W. B. Tibbets, Union Carbide Plastics Corp.; A. A. Checchi, Food & Drug Administration; R. C. Wilcox, American Can Co.; J. C. Wright, Visking Co.; G. H. Lacy, Dow Chemical Co., and L. W. Elder, General Foods Corp.

ified cresol resin. Small amounts of moisture absorbed by resin-treated paper before laminating is the primary factor determining the 60-cycle dielectric properties of the resulting laminates. As little as 1 to 1.5% moisture can cause dissipation factor to increase as much as 0.2 to 0.25. Dissipation factor drift, the increase in D.F. after water immersion, also increases with increasing moisture absorbed. The effect of absorbed moisture is far greater than that of a comparable amount of water released as water of condensation on curing the resin.

Quantitative measurements of water of condensation and moisture content were made using a combination of Dean-Stark azeotropic distillation for total water content and Fischer water content to determine free water. For a typical cresol resin impregnated paper, 50% of the volatile content is water, of which 62% is water of condensation released on curing.

Measurements have been made of the 60-cycle dielectric properties of resin-impregnated paper and of unimpregnated paper as a function of absorbed moisture content in the uncured, oven-cured, and press-cured states. These data indicate that the large increase in dissipation factor is due to association between the absorbed water and cellulose during press curing. On the other hand, water of condensation released on curing is associated with resin primarily, thus moderating its effect on electrical properties. Absorption of 2% moisture caused the dissipation factor of a lay-up of uncured impregnated paper to increase from 0.011 to 0.061; on press curing, the dissipation factor increased to 0.514. Unimpregnated paper experiences an immediate large increase for a small amount of absorbed moisture, indicating that the increase in dissipation factor is due to association of water and cellulose.

Pretreatment of paper with a small amount of low molecular weight melamine or phenolformaldehyde resin prior to impregnation with resin substantially prevents moisture absorption by the paper resulting in improved electrical properties. Electrical properties other than those at 60-cycles, particularly after water immersion, are also improved as a result of the pretreatment of the paper. When melamine resin is used, the fire resistance is also improved appreciably.

The second paper of the Plastics Laminates session was by D. M. Gilmore, Brown Co., Berlin, N. H., who presented a *"Report on TAPPI Project 763, Covering Tests for Rate of Penetration Using the Williams Penetrometer."* The Plastics Laminates Committee conducted a survey of methods of qualifying paper for saturating. It was found that the methods in use were many and varied, as were the test fluids used.

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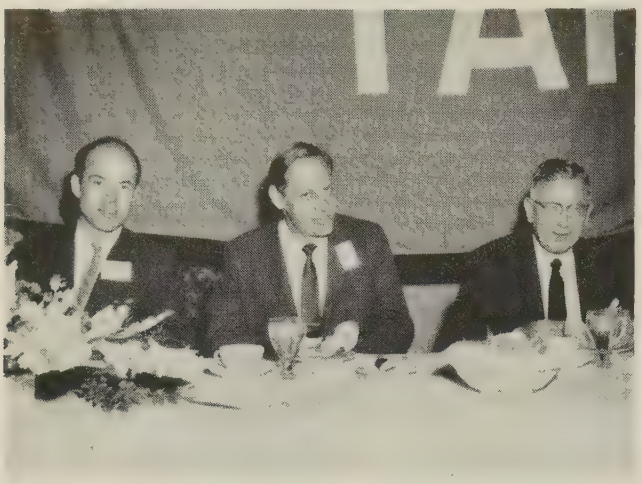
Little agreement was found among laboratories. Work is continuing within the committee, and it is hoped that a single suitable method may be worked out eventually.

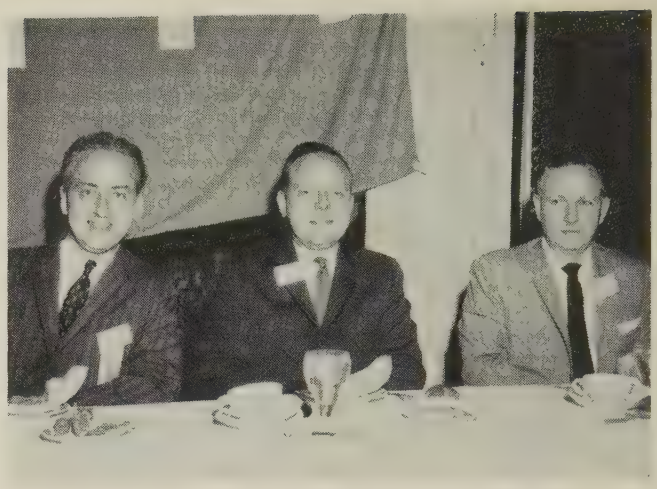
The third paper was also a committee project report, by C. A. Siconolfi, Durez Plastics Div., Hooker Chemical Co., N. Tonawanda, N. Y., and was titled *"Report on Project 764: Resin Solids Test—Development of Tests for Resin Solids in Saturated Sheets."* Work by the committee has indicated that a promising method for resin solids has been developed. Further round-robin work will be needed to establish the precision and accuracy of the method.

F. Rosenthal, Knowlton Bros., Watertown, N. Y., presented the final paper of the conference, *"Water Immersion*

Laminates Session: H. A. Spencer, Knowlton Bros.; M. Ezrin, Monsanto Chemical Co.; D. M. Gilmore, Brown Co.; C. A. Siconolfi, Hooker Chemical Corp.; and F. Rosenthal, Knowlton Bros.



Banquet head table: P. E. Nethercut, TAPPI; V. T. Stannett, State University College of Forestry; and L. K. Hanson, Continental Can Co.



Banquet head table: W. L. Hardy, International Minerals & Chemical Corp.; R. C. Sturken, Frank W. Egan & Co.; and J. C. Pullman, American Cyanamid Co.

of Resin-Saturated Papers." Mr. Rosenthal described the development of a simple and rapid control method based on the weight gain of resin-saturated paper after brief immersion in water. Immersion of sample strips in water after heating to 300°F. for 3, 5, and 10 min. provides a simple technique for determining the quality of saturation and degree of cure in papers saturated with phenolic resins. The method also lends itself to a comparison of different phenolic resins and to the study of factors affecting resin condensation and cure.

Official Banquet

The official banquet of the 14th Plastics-Paper Conference was held on Monday evening, September 21. W. L. Hardy, general conference chairman, was toastmaster. After commenting on the host city, Chicago, as a city of contrasts, Mr. Hardy introduced P. E. Nethercut, executive secretary of TAPPI, who welcomed the conferees on behalf of TAPPI President J. R. Lientz. Mr. Hardy then introduced L. K. Hanson vice-president, Continental Can Co., New York, N. Y., who gave an address on: "What Goes Over Overseas."

1960 Plastics-Paper Conference

The 15th TAPPI Plastics-Paper Conference will be held Oct. 17–19, 1960, at the Hotel Syracuse, Syracuse, N. Y. General chairman of the conference is V. T. Stannett, College of Forestry, Syracuse, N. Y.; program chairman is R. Loheed, Chas. T. Main, Inc., Boston, Mass; local arrangements chairman is C. G. Morse, Sealright-Oswego Falls Corp., Fulton, N. Y. Anyone wishing to present a paper at the conference should get in touch with Mr. Loheed as soon as possible.

45th

Annual Meeting

of the

Technical Association

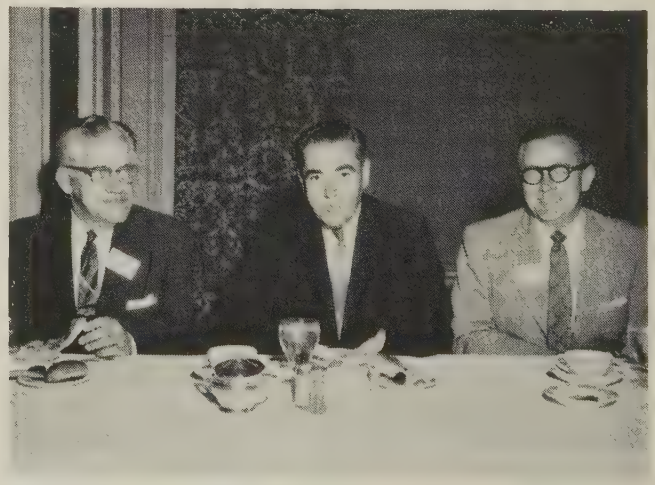
of the

Pulp and Paper Industry

Hotel Commodore, New York, N. Y.

Feb. 22–25, 1960

Banquet head table: H. O. Teeple, TAPPI; W. R. Price, Central Waxed Paper Co.; and W. N. Stickel, Texon, Inc.



Banquet head table: H. A. Spencer, Knowlton Bros.; G. H. Sullivan, H. P. Smith Paper Co.; and A. J. Winchester, TAPPI

PERSONAL MENTION

Items About New and Old Tappimen

New TAPPI Members

Salomon D. Alcalay, Manager, Almi SRL, Buenos Aires, Argentina. Attended the Politecnicum of Haifa.

Gordon L. Allan, Technical Representative, Hercules Powder Co. Ltd., London, W.1, England, a 1945 graduate of Reading University.

Nils O. Alm, Engineer, Separator Aktiebolag, Lund, Sweden, a 1950 graduate of Finlands Institut of Tecnology.

Arnold T. Anderson, Superintendent, Union Carbide Chemicals Co., Niagara Falls, N. Y. Attended McMaster University.

Earle E. Andrews, Jr., Superintendent, Rag Paper Mill, Spaulding Fibre Co., Inc., Milton, N. H., a 1943 graduate of Tufts University.

Harold W. Anway, Jr., District Sales Manager, Monsanto Chemical Co., Organic Chemicals Div., San Francisco, Calif., a 1949 graduate of Iowa State University.

Milton R. Barbe, Technical Sales, The Hubinger Co., Keokuk, Iowa. Attended Iowa Wesleyan College.

Jordan V. Bauer, Research Chemist, The Hubinger Co., Keokuk, Iowa. Attended Crane College.

Stephen Black, Mill Chemist, Premier Paper Mills Ltd., Transvaal, Union of South Africa.

Bixby W. Bonney, Laboratory Supervisor, Alaska Lumber & Pulp Co., Inc., Sitka, Alaska.

Oscar E. Bruschtein, Vice-President, Papelera Teitelman S.A.I. yC., Adrogue, FNGR, Argentina, a 1948 graduate of Facultadde Ingenieria.

John A. Burns, Jr., Plant Superintendent, The Martin Cantine Co., Saugerties, N. Y.

Connie Mack Butler, Technical Representative, Naugatuck Chemical Div., U. S. Rubber Co., Chicago, Ill., a 1955 graduate of Rollins College.

Herbert M. Byrd, President, Sonoco de Mexico, S.A., Mexico 1, D. F., a 1935 graduate of Clemson College.

Sylvester J. Campbell, Senior Engineer, Westinghouse Electric Corp., East Pittsburgh, Pa., a 1950 graduate of the University of Wisconsin.

Guy B. Clark, Packaging Physicist, Owens-Illinois, Duraglass Center, Toledo, Ohio, a 1947 graduate of West Virginia University.

Floyd E. Colvin, Laboratory Manager, Cuno Engineering Corp., Meriden, Conn., a 1950 graduate of Indiana University.

John M. Dawson, Director of Libraries, University of Delaware, Newark, Del.

Theodore E. Durst, Student, Assistant in Dept. of Chemical Engineering, University of Maine, Orono, Me. Will graduate in 1960.

Theodore R. Edwards, Technical Supervisor, Marathon Div., American Can Co., Oswego, N. Y., a 1950 graduate of Michigan College of Mining and Technology.

Harold E. Ellefson, Technical Sales Service, Clinton Corn Processing Co., Clinton, Iowa.

Richard C. Erickson, Student, Institute of Paper Chemistry, Appleton, Wis., a 1955 graduate of Ohio Wesleyan University.

John F. Fila, Technical Supervisor, Columbia Boxboard, Inc., Chatham, N. Y.

Cecil S. Flenniken, Engineer, S.I.L.C.A., Milan, Italy, a 1949 graduate of Georgia Institute of Technology.

James W. Flynn, Chemical Sales Engineer, Mobil Oil Co. Div., Socony Mobil Oil Co., New York, N. Y., a 1950 graduate of Fordham College.

Edward G. Fochtman, Supervisor, Armour Research Foundation, Chicago, Ill., a 1943 graduate of Michigan State University.

John K. French, Assistant to General Manager, Mill Operations, Continental Can Co. of Canada Ltd., Toronto, Ont., Canada, a 1940 graduate of McGill University.

Melvin A. Freytag, Assistant Maintenance Engineer, Sealright Oswego-Falls Corp., Fulton, N. Y., a 1949 graduate of New York State College of Forestry.

Eugene J. Goldsberry, Senior Project Engineer, Solo Cup Co., Chicago, Ill., a 1959 graduate of Illinois Institute of Technology.

Robert S. Grimshaw, Head, Patent Dept., West Virginia Pulp & Paper Co., New York, N. Y., a 1943 graduate of the University of Michigan.

K. Lewis Hackley, Group Leader, Research and Development Div., Champion Paper & Fibre Co., Hamilton, Ohio, a 1933 graduate of Armour Institute of Technology.

Ralph C. Hand, Section Head, Building Products Sec., The Dow Chemical Co., Midland, Mich. Attended Bay City Junior College.

Stanley L. Hepp, Sales Representative, The Hubinger Co., Keokuk, Iowa, a 1935 graduate of the University of Virginia.

John I. Hillyer, Mechanical Engineer, Ecusta Paper Div., Olin-Mathieson Chemical Corp., Pisgah Forest, N. C., a 1948 graduate of Brown University.

Peter A. Illing, Quality Service Representative, West Virginia Pulp & Paper Co., Chicago, Ill., a 1957 graduate of the University of Darmstadt.

Paul O. Jordan, Project Engineer, Food Machinery & Chemical Corp., San Jose, Calif. Attended Dunwoody Industrial Institute.

Donald C. Kaley, Assistant to Manager of Box Factories, Union Bag-Camp Paper Corp., Savannah, Ga., a 1952 graduate of Washington University.

Yutaka Kitagawa, Managing Director, Teijin Shoji Kaisha Ltd., Osaka, Japan, a 1922 graduate of Hitotsubashi University.

William P. Koppenaal, Sales Engineer, General Electric Co., Milwaukee, Wis., a 1949 graduate of the Univeristy of Wisconsin.

William R. Kuehne, Sales Engineer, Pennsalt Chemicals Corp., Philadelphia, Pa., a 1954 graduate of Drexel Institute.

G. W. Lang, Sales Engineer, Patton Mfg. Co., Inc., Springfield, Ohio, a 1950 graduate of the University of Wisconsin.

John P. La Rue, Vice-President, S. W. Hooper Corp., Delmar, N. Y., a 1948 graduate of Massachusetts Institute of Technology.

Patrick M. Lee, Chemical Engineer, Marathon Div., American Can Co., Green Bay, Wis., a 1948 graduate of the University of Wisconsin.

James R. Le Mahieu, Assistant to Technical Director, Blandin Paper Co., Grand Rapids, Minn., a 1947 graduate of Ripon College.

Bernard Le Menestrel, Assistant Director of Factory, ARJOMARI, Rives (Isere), France. Attended École Centrale des Arts and Manufacturing.

Richard E. Markham, Salesman, Kelco, New York, N. Y., a 1950 graduate of Michigan State University.

Robert K. Mays, Laboratory Manager, J. M. Huber Corp., Chemicals Div., Havre de Grace, Md., a 1949 graduate of Pennsylvania State University.

Richard H. Mazer, Manager, New Product Development, Hudson Pulp & Paper Corp., New York, N. Y., a 1954 graduate of Columbia University.

Thomas M. McCurry, Assistant Superintendent, Box Technical Dept., Union Bag-Camp Paper Corp., Savannah, Ga., a 1951 graduate of Clemson A & M College.

L. Carlton Mertz, President, L. Carlton Mertz Co., Chicago, Ill. Attended the University of Chicago.

Francis M. Myers, Superintendent, Columbia Box Board Mills, Inc., Chatham, N. Y., a 1942 graduate of Siena College.

Yas Nomiyama, Research Coating Chemist, St. Regis Paper Co., Carthage, N. Y., a 1952 graduate University of California.

Arne Normann, Sales Engineer, AG Kamyr, Karlstad, Sweden, a 1949 graduate of Cornell University.

Thomas G. Payne, Division Pulp Engineer, International Paper Co., Southern Kraft Div., Mobile, Ala., a 1940 graduate of Alabama Polytechnic Institute.

Robert C. Portouw, Vice-President, Drew Engineering Co., Portland, Ore., a 1950 graduate of Oregon State College.

Zenon Redkevitca, Project Engineer, Owens-Illinois Glass Co., Toledo, Ohio, a 1950 graduate of Massachusetts Institute of Technology, with a Ph.D. degree from Georgia Institute of Technology in 1959.

Edward A. Rosenberg, Southern Sales Manager, Thomson-National Press Co., Franklin, Mass. Attended Boston Univeristy.

Sidney P. Rubinstein, Quality Control Consultant, Franklin Park, N. J., a 1951 graduate of The College of the City of New York.

Antonio C. Sanchez, Technical Director, Papelera Chabacano S.A., Mexico, D. F., a 1949 graduate of Universidad de Puebla.

Gus S. Scarvelis, Laboratory Manager, Owens-Illinois Glass Co., Toledo, Ohio, a 1950 graduate of Polytechnique Institute of Brooklyn.

Robert F. Schwenker, Jr., Group Leader, Textile Research Institute, Princeton, N. J., a 1948 graduate of the University of Pennsylvania.

Leon K. Semke, Graduate Student, The Institute of Paper Chemistry, Appleton, Wis., a 1958 graduate of the University of Washington.

Hobart M. Setter, Setter Bros., Inc., Research and Development, Cattaraugus, N. Y. Attended University of Arizona.

Elizabeth Sloan, Librarian, Science and Technology Div., Queens Borough Public Library, Jamaica, N. Y.

Dillon F. Smith, Jr., Mechanical Engineer, St. Joe Paper Co., Port St. Joe, Fla., a 1953 graduate of the University of Florida.

J. Barry Smith, Technical Service Representative, Hercules Powder Co., Wilmington, Del., a 1956 graduate of Bucknell Univeristy.

Richard H. Snow, Research Chemical Engineer, Armour Research Foundation, Chicago, Ill., a 1956 graduate of the Illinois Institute of Technology with a Ph.D. degree.

Edmund A. Stec, Sales Engineer, Waldron-Hartig Div., Midland-Ross Corp., New Brunswick, N. J. Attended the Illinois Institute of Technology.

John R. Stephens, Assistant Chief Electrical Engineer, Champion Paper & Fibre Co., Canton, N. C., a 1943 graduate of Clemson A & M College.

Bernard R. Suares, Sales Manager, Dorr-Oliver, Paris, France, a 1950 graduate of École Physique et Chimie.

Frey V. Sundman, Chief Laboratory Engineer, A. Ahlstrom Oy, Kauttua, Finland, a 1941 graduate of Abo Akademi.

Arthur W. Tackaberry, Chief Engineer, MacSim Bar Paper Co., Otsego, Mich., a 1939 graduate of Queen's University.

Carroll Taylor, Technical Sales Representative, The Hubinger Co., Keokuk, Iowa.

George R. Teslik, Field Engineer, Elliott Company, Milwaukee, Wis., a 1952 graduate of the University of Pittsburgh.

George A. Tiffany, Technical Representative, Sales, Hercules Powder Co., Detroit, Mich., a 1953 graduate of Lehigh University.

Harold F. Tolnitch, Sales Manager, Machine Knife Products, Simonds Worden White Co., Dayton, Ohio. Attended Princeton University.

Gerald F. Touzinsky, Student, The Institute of Paper Chemistry, Appleton, Wis., a 1956 graduate of Marquette University.

Wilbur E. Trennepohl, Technical Service, A. E. Staley Mfg. Co., Decatur, Ill.

Vernon H. Truesdale, Technical Supervisor, Consolidated Water Power & Paper Co., Appleton, Wis., a 1938 graduate of Indian Central College.

Kenneth J. Van Arnum, Manager, Market Research, California Chemical Co., San Francisco, Calif., a 1942 graduate of Ohio State University.

Wallace E. Voeks, Research Assistant, Institute of Paper Chemistry, Appleton, Wis., a 1955 graduate of Ripon College.

Peder Waern-Bugge, Civil Engineer, Royal Institute of Technology, Papermaking Dept., Stockholm, Sweden.

Arthur G. Walsh, Director of Engineering, Dixon Chemical & Research, Inc., Bloomfield, N. J., a 1940 graduate of Tufts University.

Robert G. Weisz, Group Leader, Amoco Chemicals Corp., Chicago, Ill., a 1952 graduate of Texas Technological College.

Robert S. Westwater, President, Atlantic Bearings Corp., Cambridge, Mass., a 1944 graduate of Missouri School of Mines.

Harry G. White, Mechanical Engineer, St. Joe Paper Co., Port St. Joe, Fla., a 1955 graduate of Indiana Technical College.

Robert M. Winkler, Chemist, Howard Paper Mills, Inc., Aeton Paper Co. Div., Dayton, Ohio, a 1958 graduate of Defiance College.

Obana Yoshimasa, Director, Administrative Office, Fuji Mill, Kokoku Rayon & Pulp Co. Ltd., Yoshiwara City, Shizucka Pref., Japan, a 1947 graduate of Tokyo University.

TAPPI Notes

Henry J. Abernathy, formerly of Columbia Boxboard, Inc., is now with Whippany Paper Co., Whippany, N. J.

Herman R. Amberg is now Plastics Research Manager for Crown Zellerbach Corp., Camas, Wash.

Roy S. Arrandale has been transferred from Elmira, N. Y., to New York, N. Y., as Vice-President in charge of Research & Engineering of Thatcher Glass Mfg. Co., Inc.

Ernst Back, formerly of Swedish Forest Products Research Laboratory, is now Senior Research Chemist, Central Laboratory, Swedish Fiber Building Board Industry, Stockholm, Sweden.

Arthur A. Baker, formerly of Oldbury Electro-Chemical Co., is now Sales Manager for Warner Chemical Products, Inc., Muncie, Ind.

Raymond E. Baker is now Vice-President, manufacturing for Weyerhaeuser Timber Co., Tacoma, Wash.

Melvin J. Beagle has been transferred from Houston, Texas, to Chicago, Ill., as Chemical Engineer of Swenson Evaporator Co.

A. L. M. Bixler, formerly of Riegel Carolina Corp., is now Vice-President in charge of Manufacturing for Hamilton Paper Co., Miquon, Pa.

Roger W. Capwell has been transferred from Stroudsburg, Pa., to Garfield, N. J., as Director, Quality Control, Coates Board & Carton Co., Inc.

Robert E. Cates, has been transferred from Wilmington, Del., to Mobile, Ala., as Technical Service Engineer, Hercules Powder Co.

John L. Burton, has been transferred from Chicago, Ill., to College Point, N. Y., as Research Chemist, Lily-Tulip Cup Corp.

George A. Charters, formerly of Western Waxide Div., Crown Zellerbach Corp., is now Supervising Engineer for Bechtel Corp., San Francisco, Calif.

Neil H. Christian is now Production Manager for Nekoosa Paper Co., Port Edwards, Wis.

Charles E. Colgan has been transferred from Kensington, Conn., to Chicago, Ill, as Research Engineer of Continental Can Co., Inc.

Derek G. Curie is now Vice-President—Manager for Weyerhaeuser Timber Co., Tacoma, Wash.

William J. Cusack, Jr., has been transferred from Carthage, N. Y., to Sartell, Minn., as Group Leader, Quality Control of St. Regis Paper Co.

Richard A. Dando has been transferred from Deferiet, N. Y., to Carthage, N. Y., as Technical Service Engineer of St. Regis Paper Co.

Dave C. Dowd, formerly of Charles Dowd Box Co., Inc., is now President for Specialty Equipment Corp., Worcester, Mass.

Harry D. Eliason has been transferred from Kalamazoo, Mich., to La Jolla, Calif., as Assist. Vice-President of Cellulose Sales Co.

Donald M. Ferguson has been transferred from Deferiet, N. Y., to Carthage, N. Y., as Supervisor of Technical Service to Manufacturer of St. Regis Paper Co.

Peter J. Fitzpatrick has been transferred from Boston, Mass., to Charlotte, N. C., as Technical Representative of American Cyanamid Co.

Kenneth Froman, formerly of West Virginia Pulp & Paper Co., is now Associate Chemist for International Business Machines, Lexington, Ky.

Carl J. Gaudet, formerly of Standard Paper Mfg. Co., is now Fine Paper Specialist, Champion Paper & Fibre Co., Canton, N. C.

Fred Gram, formerly of A. Ahlstrom Oy, is now Technical Manager for Svenska Cellulosa A/B Matfors Pappersbruk, Matfors, Sweden.

A. Stanley Gregory is now Director, Research Division for Weyerhaeuser Timber Co., Longview, Wash.

John B. Griffith is now Sulphite Mill Shift Foreman for Crown Zellerbach Corp., Camas, Wash.

Sven Haglund is now Resident Manager for Jossefors Bruk, Jossefors, Sweden.

Frank V. Halvonik, formerly of P. H. Glatfelter Co., is now Director of New Product Development & Technical Sales for Monadnock Paper Mills, Inc., Bennington, N. H.

John S. Hart, formerly of Pulp & Paper Research Institute of Canada, is now Process Engineer for St. Lawrence Corp. Ltd., Montreal, P. Q., Canada.

Akira Hatano has been transferred from Seattle, Wash., to Sitka, Alaska, on the Technical Staff of Alaska Lumber & Pulp Co., Inc.

John T. Hegeman, formerly of Brown Co., is now Production Manager for Celgar Ltd., Vancouver, B. C., Canada.

Manne Helgegren, formerly of Sprout, Waldron & Co., Inc., is now Project Engineer for West Virginia Pulp & Paper Co., Luke, Md.

Raymond A. Hill, Jr., is now Plant Manager for Congoleum-Nairn, Inc., Wilmington, Del.

Henry S. Hooper, formerly Technical Director for Penobscot Chemical Fibre Co., Great Works, Me., is retiring as of Nov. 1, 1959.

Lloyd Hornbostel is now Technical Assistant to the President for Beloit Iron Works, Beloit, Wis.

William A. Hosmer is now Superintendent, Willow Mill for Hurlbut Paper Co., South Lee, Mass.

Nils F. Janson has been transferred from Mechanicsville, N. Y., to Sandusky, Ohio, as Manager of Manufacturing Services, Hinde & Dauch Division of West Virginia Pulp & Paper Co.

Hannes A. Jansson, formerly of Joutseno Pulp Oy, is now Technical Manager for Kemi Oy, Sulphate Pulp Mill, Karihaara, Finland.

Daniel Rodriguez Jimenez is now Assistant Superintendent for Cia. De Las Fabricas De Papel De San Rafael Y Anexas, S.A., Estado De Mexico.

James G. Johns has been transferred from Philadelphia, Pa., to Baltimore, Md., as District Sales Manager of Olin-Mathieson Chemical Corp.

Edward W. Keith, formerly Vice-President and Manager of Mills for Penobscot Chemical Fibre Co., Great Works, Me., is retiring as of Nov. 1, 1959.

Thomas M. Keville, Jr., has been transferred from Haverhill, Mass., to Elkhart, Ind., as Assistant to Superintendent of Continental Can Co., Robert Gair Paper Group.

Gilbert E. Kohr has been transferred from Hamilton, Ohio, to Watertown, N. Y., as Sales Engineer of The Black-Clawson Co., Paper Machine Division.

Bernard J. Koziol has been transferred from Middletown, Ohio, to Watertown, N. Y., as Staff Sales Engineer of The Black-Clawson Co.

William H. Kreiling, formerly of Lowe Paper Co., is now Chemical Engineer, Research Division, for Keuffel & Esser, Hoboken, N. J.

Raymond A. Labbe has been transferred from Greeneville, Tenn., to Knoxville, Tenn., as Field Service Engineer of Formex Co., Division of Huyck Felt Co.

Frank S. Landers has been transferred from Chicago, Ill., to College Point, N. Y., as Research Engineer of Lily-Tulip Cup Corp.

L. K. Larson is now Vice-President, Sales, for Weyerhaeuser Timber Co., New York, N. Y.

Harold J. Lausman is now Division Manager for Consolidated Water Power & Paper Co., Appleton, Wis.

George W. Legg, formerly of Pulp & Paper Research Institute of Canada, is now Manager, Pulp & Paper Service Dept., for Standard Chemical Ltd., Montreal, P. Q., Canada.

Ellis Lehman is now Technical Sales Representative for A. E. Staley Mfg. Co., Decatur, Ill.

Donald W. Libby has been transferred from Norwich, Conn., to Manistee, Mich., as Chemical Engineer of Continental Can Co.

Harold G. Macklem, formerly of Boise Cascade Corp., is now Plant Engineer for Dierks Paper Co., Pine Bluff, Ark.

Frank W. Major, formerly of Hammermill Paper Co., is now Chemist for Imperial Color Chemical & Paper Corp., Glens Falls, N. Y.

James A. Marcalus has been transferred from Paterson, N. J., to Los Angeles, Calif., as Engineer of Specialty Paper & Board Mills, Inc.

Robert C. Margiloff has been transferred from Cumberland Mills, Me., to Boston, Mass., as Technical Adviser, Quality Control of S. D. Warren Co.

Harold M. Morris has been transferred from Pasadena, Tex., to Canton, N. C., as Assistant Product Manager of Champion Paper & Fibre Co.

Adriaan P. Neeb of Van Gelder Zonen N. V. has been transferred from Renkum, The Netherlands, to Arnhem, The Netherlands.

Bjarne Th. Nyman, formerly of Oy Kyro AB, is now Works Manager for A. Ahlstrom Oy, Karhula, Finland.

Rolf F. Oberg, formerly of Valmet Oy, Rautpohjan Factory, is now Managing Director for Wartsila-Koncernen A/B, Wasa Mek. Verkstad, Finland.

J. Robert O'Grady is now Chief Engineer for Carthage Machine Co., Carthage, N. Y.

Sture G. Olsson is now President and General Manager for The Chesapeake Corp. of Virginia, West Point, Va.

James D. Parmele is now Administrator of Laboratories, Technical Division for St. Regis Paper Co., Deferiet, N. Y.

Edgar M. Pierce, formerly of Dravo Corp., is now Partner for E. M. Pierce & Associates, Largo, Fla.

James M. Piette has been transferred from Savannah, Ga., to Franklin, Va., as Assistant Mill Division Manager of Union Bag-Camp Paper Corp.

Henry J. Powell is now Chemist for Riegel Paper Corp., Acme, N. C.

Warren R. Price, formerly Consulting Chemical Engineer, is now Technical Director for Central Waxed Paper Co., Chicago, Ill.

Keith Provo is now General Production Manager for Gaylord Container Div., Crown Zellerbach Corp., St. Louis, Mo.

Hyman L. Rammer has been transferred from San Francisco, Calif., to Antioch, Calif., as Technical Superintendent of Fibreboard Paper Products Corp.

Robert W. Reed has been transferred from Jacksonville, Fla., to New York, N. Y., as Director, Technical Service & Control of St. Regis Paper Co.

Alonzo Richardson is now Engineering Manager for Gaylord Container Corp. Div., Crown Zellerbach Corp., St. Louis, Mo.

Robert. L. Ringwood is now Sales Manager for Henry Pratt Co., Chicago, Ill.

Aaro J. Saarikko, formerly of Eastern Corp., is now Project Engineer for Celgar Ltd., Vancouver, B. C., Canada.

Laurin S. Sabatke is now Plant Manager for Marathon Div., American Can Co., Menominee, Mich.

Charles H. Sailer, formerly of Anglo Canadian Pulp & Paper Mills, is now Assistant to the General Manager for Millspaugh Wimpey Ltd., London, England.

Frederick B. Schelhorn is now Vice-President, Applied Research and Development of the Forest Products Group for Owens-Illinois Glass Co., Mill Div., Toledo, Ohio.

Roger A. Schwartz, formerly of Knowlton Brothers, is now Project Chemist, Technical Service Laboratory for St. Regis Paper Co., Carthage, N. Y.

William J. Shaughnessy, formerly of Albany Felt Co., is now Paper Technical Representative for A. E. Staley Manufacturing Co., Decatur, Ill.

John B. Spencer, Jr., is now General Manager for Caxton Paper Mills Ltd., Kawerau, Bay of Plenty, New Zealand.

Reavis C. Sproull, formerly of Philip Morris & Co. Ltd., Inc., is now Director of Research & Development for The Chesapeake Corp. of Virginia, West Point, Va.

Richmond M. Stampley is now Sales Manager for West End Chemical Co., Div. of Stauffer Chemical Co., Oakland, Calif.

Donald A. Stanek, formerly of Sutherland Paper Co., is now Coating Group Leader for Diamond National Corp., Middletown, Ohio.

F. A. Stovink is now Regional Manager for American Cyanamid Co., Boston, Mass.

James E. Sullivan, formerly of Brown-Bridge Mills, Inc., is now Technical Sales and Service for Central Soya Co., Inc., Chicago, Ill.

Edward Taub is now Vice-President for Interstate Container Corp., Glendale, L. I., N. Y.

Leon B. Timmerman has been transferred from Atlanta, Ga., to Buffalo, N. Y., as Pump Specialist of Buffalo Pumps Div., Buffalo Forge Co.

John G. Turk, formerly of Owens-Illinois Glass Co., is now Director, Package Research Laboratory for Glass Container Manufacturing Institute, East Lansing, Mich.

Joseph F. Voit, formerly of The Glidden Co., is now Sales Manager for Ralston Purina Co., Special Soy Product Div., St. Louis, Mo.

Per Borje Wahlstrom, formerly of Korsnas AB, is now Research Director, Paper Machinery, for Karlstads Mekaniska Werkstad, Karlstad, Sweden.

Joshua J. Ward, Jr., has been transferred from Hamilton, Ohio, to Canton, N. C., as Director, General Plant Engineering of Champion Paper & Fibre Co.

William J. Weiss, formerly Student at University of Maine, is now Chemical Engineer for Union Bag-Camp Paper Corp., Savannah, Ga.

Francis O. Whipple is now Product Development Manager for Canadian Western Lumber Co., Crown Zellerbach Div., Vancouver, B. C., Canada.

Lester M. Whitmore, Jr., formerly of Sulphite Pulp Manufacturers Research League, is now Chief, New Products Research for Scott Paper Co., West Coast Div., Everett, Wash.

Leo B. Wickstrom, formerly of Ortvikens Pappersbruk (Svenska Cellulose AB), is now Technical Manager for Nordiska Maskinfilt AB, Gamletullsgatan, Halmstad, Sweden.

Czeslaw J. Witkowski, formerly of Fabrica De Papel Coyoacan S.A., Mexico, D. F., is now Project Engineer for Dorr-Oliver, Inc., Stamford, Conn.

Earl R. Wolcott, formerly of West Virginia Pulp & Paper Co., is now Project Engineer for M. W. Kellogg Co., New York 17, N. Y.

A. Dale Wolvin is now Quality Control Director for Wyerhaeuser Co., Shipping Container Div., Chicago, Ill. (Formerly of Eddy Paper Corp.)

Leonard J. Wood, Jr., is now Product Manager, Paper Division, National Starch and Chemical Corp., New York, N. Y.

Arne A. Wretne, formerly of West Virginia Pulp & Paper Co., is now Sales Manager for Rosenblad Corp., New York, N. Y.

Karl Zappert, formerly of Industrias Klabin Do Parana De Celulose S.A., Parana, Brazil, is now Technical Director for Bunzl Pulp & Paper Ltd., London, England.

* * *

Lucien Barrez, President Directeur General of the Soc. Normande De Carton Ondulé, Drancy (Seine), France, is official corporate representative in TAPPI.

* * *

H. L. Jaffe has succeeded E. J. Hill as the official representative of the Colton Chemical Co. in the Technical Association.

James P. Casey, Director of Starch Sales, has succeeded E. B. Pulse as the official representative of the Union Starch & Refining Co. in TAPPI.

Industry Notes

PRODUCTION

Production of paper and paperboard in August, 1959, totaled an estimated 2,990,000 tons*. This brought the production total for the first 8 months of the year to 22,694,000 tons, to mark a gain of 13.4% over the corresponding 1958 total. All major sectors of the paper and paperboard industry continued to show gains; production of paper in the first 8 months was about 12% above the year-earlier level; production of paperboard about 15%; while production of construction paper and board was up about 16%. Preliminary data on the rate of operations indicate that the rate of production of paper and paperboard in September, 1959, after adjustment for the Labor Day holiday, continued at about the August rate. This would indicate a monthly total for September of about 2.88 million tons, which would be 9% above the September, 1958, total. Note, however, that the rate of operation in the paper and paperboard

industry picked up sharply in the last 5 months of 1958, so that the year-to-year percentage gains for the remainder of 1959 will undoubtedly be much smaller than they were in the first half of this year.

* from APPA, *Monthly Statistical Summary* 37, No. 9.

Pulpwood

Total receipts of pulpwood for the first 7 months of 1959 were 21,267,000 cords, an increase of 2,253,000 cords over receipts for the comparable period of 1958. Domestic receipts were 2,380,000 cords above the year-earlier total, while imports declined 127,000 cords. All of the regions showed increases ranging from 4% in the West, to 15% in the South Atlantic.

Pulpwood consumption in the first 7 months of 1959 was 22,333,000 cords, an increase of 2,489,000 cords over the same period of 1958. All of the regions showed increases ranging from 1% Northeast to 18% South Atlantic.

Inventories of pulpwood at the end of July were 4,849,000 cords, an increase of 179,000 cords above June, 1959, and a 944,000 cords decline from July last year. Four of the regions showed decreases ranging from 10% South Atlantic to 28% West. The South Central region showed an increase of 22%.

Wastepaper and Other Fibrous Materials

July wastepaper receipts were 763,000 tons; for the first 7 months of this year they totaled 5,436,000 tons, an increase of 559,000 tons above receipts for the first 7 months of last year.

Wastepaper consumption for July was 728,000 tons; the January–July total was 5,346,000 tons, an increase of 443,000 tons above consumption for the first 7 months in 1958.

Inventories at the end of June were 527,000 tons, an increase of 35,000 tons above June, and 39,000 tons above inventories at the end of July, 1958.

Consumption of total fibrous materials for July was 812,000 tons; the January–July total was 5,965,000 tons, an increase of 1,158,000 tons above consumption for the first 7 months of 1958.

Inventories of total fibrous materials at the end of July were 908,000 tons, 38,000 tons below June, and 49,000 tons above inventories at the end of July, 1958.

Wood Pulp

Production of wood pulp for the first 7 months of 1959 was 13,969,000 tons, an increase of 1,903,000 tons above the comparable 1958 total.

Wood pulp consumption in the manufacture of paper and board for the first 7 months of 1959 was 14,483,000 tons, an increase of 2,014,000 tons above consumption for the first 7 months of 1958.

Imports of wood pulp for January–June, 1959, were 1,425-562 tons, an increase of 24% above imports for the first 7 months of last year. Imports from Canada for the first 7 months of 1959 were 1,163,141 tons, an increase of 14% over the comparable period of 1959. Overseas imports for the first 7 months of 1959 were 558,898 tons as compared to 141,046 tons in the first 7 months of 1958.

Exports of wood pulp for the first 7 months of this year were 346,650, tons, as against 313,452 tons exported during the same period last year.

Inventories of wood pulp at paper and board mills at the end of July were 547,000 tons, an increase of 1000 tons above inventories at the end of June and 4000 tons below inventories at the end of July, 1958.

Southern Rhodesia

An extensive deposit of high grade pollucite ore has been developed at the Southern Rhodesia, Africa, operations of Bikita Minerals (Private) Ltd., according to an announcement by American Potash & Chemical Corp., which handles the sale of Bikita products.

Tests indicate the deposit is one of the largest in the world and offers a reliable supply of low-cost pollucite, an aluminum-cesium silicate, for cesium applications in such industries as glass and ceramics manufacturing, in welding rod fluxes and other uses where silica can be utilized along with the cesium. Pollucite in the Bikita deposit averages 24.4% cesium oxide.

Cesium in the past has been available only in small quantities until American Potash recently began sales of cesium metal and cesium compounds produced from lepidolite lithium ore at San Antonio, Tex.

A potential use for cesium is in ion-propulsion engines for space travel. Under development at present, this type of engine produces small thrust but becomes practical in outer space after a vehicle's initial speed has been provided by rockets or other power source. The ion-propulsion engine then will operate on an interplanetary range.

Dominican Republic

Industrias Niguas, an enterprise financed wholly by Dominican Republic Capital, has been founded in Ciudad Trujillo for the production of articles greatly consumed in the country but at present imported largely from abroad.

The principal aim of the new company is the manufacture of all kinds of paper bags, notebooks, office paper, and sanitary paper. Equipment for making multiple-layer bags and sanitary paper has already reached Ciudad Trujillo.

New York

The State of New York has acquired 2880 acres of land to be added to the forest preserve and Adirondack Park. This land acquisition was made possible through an outright gift from Finch, Pruyn and Co., Glens Falls, N. Y., one of the largest private land owners in the Adirondack Mountains. The tract is located in the townships of North Hudson and Schroon in Essex County and includes Hoffman Mountain in Blue Ridge. This area is particularly valuable to the state as it is already surrounded by other state-owned land.

Louisiana

The Louisiana Forestry Commission has published a 55-page *History of Forestry in Louisiana.* It relates the story from the rise of lumbering in the 1870's down to the present.

Portable Gas Station

Goodyear Tire & Rubber Co., Aviation Products Div., has developed an air-transportable hydrant fueling system which meets the strictest requirements of the military.

The new system will accommodate 50,000 gal. of fuel, can be transported in one aircraft along with all tools, applicable ground support equipment, and personnel necessary for assembly and operation.

The storage system includes five 10,000-gal. collapsible Pillow Tanks manufactured by Goodyear. The pumping and delivery system is composed of equipment supplied by Bowser, Inc., who worked on the system in conjunction with Goodyear.

The hydrant is able to fuel Air Force jet aircraft at a rate varying from 150 to 600 g.p.m. It also can provide re-circulation, filtration and water removal for the initial supply of fuel without having to waste or dump any fuel prior to fueling the first aircraft.

Despite different mission requirements and varying topographical and climatic conditions, the system can be expanded or reduced in capacity without affecting its ability to deliver clean, dry fuel.

Portable gas station developed by Goodyear and Bowser, Inc.

It can be transported completely in a C-124 cargo plane, along with necessary ground support equipment and personnel. Estimated time of erection is 12 hr.

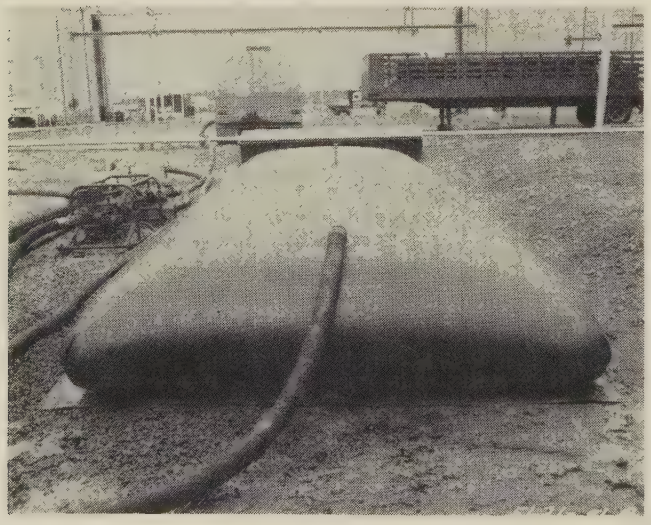
The system is provided with an adapter kit mounted on a cart which has the necessary fittings and tools to join with practically any type of fuel source, including a cross-country hose or pipe line, tank trucks, tank cars, fuel drums, tanker aircraft, and many others.

The Goodyear-Bowser system weighs nearly 28,000 lb., is designed to resist damage, and is nonexpensive.

Pillow Tanks

A one-million-dollar contract for five hundred 10,000-gal. pillow-type storage tanks has been awarded to the Goodyear Tire & Rubber Co. by the Army Corps of Engineers, the firm announced recently.

It is the second major contract received by Goodyear in



Pillow tanks

the past year from the Corps of Engineers. The two orders call for more than 1100 of the rubberized fabric storage tanks at a cost of nearly 2.5 million dollars.

The 10,000-gal. tanks, which look like giant-sized pillows, are 40 ft. long, 10 ft. wide, and 4 ft. high when filled. They are constructed of synthetic rubber-coated nylon, are easy to handle, and can be rolled up like a rug when not in use.

Hemicellulose Degradation

Research conducted at the Buckeye Cellulose Corp. Laboratories has succeeded in accumulating new evidence to support the existing theory of hot alkaline degradation of hemicellulose. According to R. W. Collier, who reported the results at the 136th National Meeting of the ACS, reaction rate constants have been established which place the degradation of a quantitative basis. By using the constants, the effect of a given set of processing conditions on the concentration of dissolved hemicellulose can easily be predicted.

Chip Car

A new freight car designed specifically for wood-chip traffic holds $2^1/_2$ times the volume of chips that standard hopper cars carry.

Built by SR the car has a capacity of 6800 cu. ft. and will hold approximately thirty-five 190 cu. ft. "units." Southern

New wood chip car of Southern Railway

allows a 20% reduction on the regular rate for all units in excess of 25 loaded in a car.

The cars are normally loaded by either an overhead conveyor or blowpipe system at the chipping plants. Unloading can be rapidly accomplished with a Southern-designed mechanical loader that travels on a beam alongside the unloading track. The swiveling boom of the unloader angles through the chips and rakes them into a pit beneath the track. It can clear a car as fast as the pit conveyor can move the chips into the mill. The device is not patented and Southern will make the design available to any potential user.

Fourth Pulp, Paper Conference at WMU

"Advances in the Mechanical Treatment of Fibers" is the subject for the fourth annual Pulp and Paper Conference at Western Michigan University, to be held Thursday, January 21, in the Paper Industry Laboratories.

CPPA

1960 Annual Meeting

The 1960 annual meeting of the Technical Section, CPPA, will be held at the Queen Elizabeth Hotel, Montreal, on the last Tuesday, Wednesday, Thursday, and Friday of January, 26–29th. This is a departure from previous practice, in that sessions will begin at 2:00 p.m. on Tuesday and will end at noon on Friday. The registration desk will open at 9:00 a.m. on Tuesday and a products display will be held concurrently with the meeting.

Anyone wishing to present a paper at this meeting should contact Douglas Jones, Executive Secretary, Technical Section, Canadian Pulp and Paper Association, 2280 Sun Life

Building, Montreal 2, P. Q. Summaries of proposed papers should be submitted along with the requests.

Delegates should make their hotel reservations early. Requests for accommodations should be addressed to Nelson Verge, Rooms Division Manager of the Queen Elizabeth Hotel. Give the date and time of your arrival and advise the hotel if your are a member of the Technical Section. The Technical Section does *not* handle room reservations.

If the Queen Elizabeth is unable to handle your requirements, other suitable hotels in the area are: Berkeley, LaSalle, Laurentien, Queens, Ritz Carlton, Royal Embassy, Windsor, and Sheraton-Mt. Royal.

Mensuration of Felled Trees

The Northeastern Forest Experiment Station, USDA, Upper Darby, Pa., has published Station Paper No. 117, entitled *A Method of Estimating Cubic Volume in Felled Trees*. A new method is given for computing the gross volume of felled trees, or section of trees, together with examples of procedures, and calculating aids in the form of circular slide rules and tables.

Forestry Film

The story of modern forestry in the Pacific Northwest is dramatized in a new motion picture produced by Weyerhaeuser Co. and now available for free showing to local groups.

"Tomorrow's Trees," a 30-minute film, may be requested from Weyerhaeuser Co., Tacoma Building, Tacoma 1, Wash.

Pulping Effluent Toxicity

Recent research of the Fisheries Chemistry Laboratory of Kyushu University, Japan, investigated the cause of toxicity of alkaline pulping effluent to fish and plankton organisms. The poisonous substances, which were found to be present in higher concentrations in knot cooks than in chip cooks, were soluble in ether, and precipitated when the waste was acidified. Analysis indicated that pitch abietic acid was the most poisonous substance, the 24-hr. lethal concentration being 5 p.p.m.

Request for a translation of this paper, should be made to the National Council for Stream Improvement, Inc., 271 Madison Ave., New York 16, N. Y. The reference is: Kawabe, Katsumi, "Studies on the Purification of Industrial Wastes, No. V." *Bul. Jap. Soc. of Scientific Fisheries* 21 (1): 37–41, 1955.

American Standard Pallet Sizes

A newly published American Standard can help solve a materials handling problem that has plagued almost every industry that uses lift trucks. Titled "American Standard Pallet Sizes, HM1.1–1959," it provides for 11 standard pallet sizes.

Eight rectangular pallets and three square pallets are called for in the new Standard, which has been approved by the American Standards Association and published by The American Society of Mechanical Engineers.

The ASA pallet standardization project is sponsored by ASME and the Society of Packaging and Handling Engineers. The publication includes a series of charts, or areagrams, for various standard-size carriers. For example, pallet size R-3, 36 × 42 in., is most effective for a standard 50-ton boxcar, allowing 1 in. clearance with no overhang. Areagrams for pallet loads with $1\frac{1}{2}$ in. overhang are also included.

In addition to areagrams for each size of pallet, there are charts for computing volumetric efficiency in relation to height of load.

Four of the American Standard pallet sizes are being proposed by the International Organization for Standardization (ISO) as international standards recommendations: R2, 32 × 40 in.; R4, 32 × 48 in.; R6, 40 × 48 in.; and R8, 48 × 72 in.

An International Pallet Pool has been established by the European Council of Ministers of Trade which permits only one size to be used, 32 × 48 in. The International Chamber of Commerce has endorsed the International Pallet Pool, and methods of giving preferential treatment and reduced rates to goods shipped on this size are being considered. This size is included in the new standard and is designated R4.

American Standard Pallet Sizes, MH1.1–1959, is available at $2.00 a copy from The American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y., or from the American Standards Association, 70 East 45th St., New York 17, N. Y.

Women Scientists

A first job survey of women college graduates showed that of nearly 88,000 who graduated in June, 1957, 42,000 chose teaching for a profession, 586 women had jobs as chemists, and 703 as mathematicians and statisticians.

Science in High School

The American Association for the Advancement of Science has made available to 100 selected schools an Elementary School Science Library. The library consists of 100 carefully chosen books on science and mathematics for children in the first to sixth grades and will be circulated without charge. The new project will run concurrently with the very successful five-year-old Traveling High School Science Library Program. It was organized primarily because investigations carried on by Science Service indicate that the majority of the winners in the National Science Fairs and the Westinghouse Science Talent Search developed their interest in science by the time they entered the sixth grade; and also because of the conclusion reached individually by several agencies (to say nothing of observations by parents) that lifetime reading habits are formed in early childhood.

Printing Inks

Printing inks are all around us. They surround us in our homes, our work, our shopping centers.

What are printing inks and what's "inside" them? How are they classified and how are they made? How are they tested and controlled? Where and how are they applied and used?

In the language of printers or inkmakers the five main printing processes—the five most common ways of applying ink to a surface are: letterpress, offset (or lithography), gravure, flexography, and silk-screen process.

Letterpress printing applies ink to a surface by means of raised surfaces on the printing plate or cylinder. Gravure printing applies the ink by means of "intaglio" or sunken surfaces etched into a copper printing cylinder. Offset printing or lithography prints from a plane surface with no depressions or relief. Flexographic printing operates on the letterpress principle but uses liquid instead of paste inks, like true letterpress, and prints from rubber instead of metal plates. Silk-screen printing impresses the ink through the mesh of a silk-screen stencil onto the printing surface.

Every printing ink made today is a mixture of a coloring material finely dispersed in what is called a "vehicle." The coloring material is generally a pigment, but it may be a dye, or it may be both. The vehicle consists of an oil or a solvent together with a resin. The resin's job is to act as a binder when the print is dry—to bind the coloring material to the printed surface. Sometimes the vehicle also contains small amounts of other substances—"driers" to speed up drying in certain printing processes, or chemicals added to give the ink special properties for end uses.

There are many ways of classifying inks. One of the most useful classifications groups them by the way they dry, because this is generally determined by the chemical nature of the vehicle. Looking at inks in this way, we find five common types:

1. Inks which dry by the *absorption* of the vehicle into the paper; there are nondrying, penetrating oils in their vehicles; e.g., newspaper ink.

2. Inks which dry by *oxidation.* These inks use drying oils in their vehicles, oils which absorb oxygen from the air. This hardens the ink and changes it from a liquid to a solid film. Many of today's offset and letterpress inks are oxidation drying inks.

3. Inks which dry by *evaporation.* Using volatile solvents in their vehicles, these inks dry as soon as the solvent evaporates, e.g., gravure and flexographic inks, and most silk—screen process inks.

4. *Heat-setting* inks, made from high-boiling, slow-evaporating petroleum oils and solvents also dry by evaporation but require the assistance of heat. Used in offset and letterpress printing, these inks have excellent press stability, and dry instantaneously with the application of heat.

5. *Moisture-setting* inks employ resins which are not soluble in water, in a water-soluble liquid. Thus, when they come into contact with moisture, they precipitate out of the solution, carrying the pigments onto the paper surface. In some methods of printing, there is sufficient moisture in the paper and air to cause the action. In others, a spray, usually steam, is used to accelerate it. These inks are widely used in the printing of food packages because they are odorless.

Inks made for other types of drying are cold-setting inks, wax-setting inks, and quick-setting inks.

To see how printing inks are made, let us follow an ink along the "production line."

Before the production of an ink, raw materials are carefully tested: Pigments are checked for color, ease of grinding and tinting strength; resins are investigated for clarity, solubility, color and other properties; oils are observed for viscosity, color and acid number; solvents are tested for boiling range, solvent power, purity and water content.

After all materials have been tested, a small experimental batch of the new ink is made in the laboratory. This batch is formulated exactly to meet all the customer's specifications. Taking a sample of this ink, a "drawdown" is made to see how the new batch compares with a given standard for such inks. A drawdown is a smear of the two inks, side by side, on a flat surface in order to make a visual comparison of masstone and color.

Now the factory production begins. Pigment, solvent or oil, drier and any other additives that may be needed for the particular type of ink—all ingredients are carefully weighed out and poured into a giant mixer which blends them together into one homogeneous mass. If the ink is a heavy, pasty ink made with oils, it is poured into a mill where smooth rollers apply as many tons of pressure as necessary to provide the final blending, to break up all remaining pigment agglomerates and disperse the pigment completely through the vehicle.

If the ink is a fluid, solvent-type ink such as flexographic or gravure ink, the dispersing and blending takes place simultaneously in a ball mill. Grinding takes place when the rotation of the drum causes the ball charge to cascade from the side of the drum breaking up the pigment and binder particles. A colloid mill with two grinding plates is used for certain special blending operations.

As soon as the finished ink comes from the mill, a control sample is taken for laboratory comparison with the original experimental batch. And now begins the amazing series of tests that insure quality control in every printing ink that leaves an ink factory.

The early inkmaker had a simple means for testing his ink: he would look at it, feel it, smell it, and then decide whether it was good enough for his customer's needs. Today printing inks are subjected to more rigid scrutiny.

First of all, another drawdown is made. Color and masstone of the factory ink is compared with color and mass of the experimental batch. They must be the same. Secondly, the two inks are run side by side on a proof press, where production press conditions are simulated. Some factory laboratories also have production-size presses of their own—offset, gravure, letterpress and flexographic presses installed primarily for research and development work, but also for testing new inks under real pressroom conditions.

The ink samples are subjected to the rigid tests of many other instruments: Viscometers, the Fadeometer, which subjects them to the equivalent of months of sunshine in a matter of days testing their resistance to fade; the Weatherometer, by alternately spraying water on the inked prints and exposing them to high intensity arc light, produces weathering conditions that sometimes break down inks that have withstood the Fadeometer tests (if desired, six months of outdoor exposure to the roughest weather can be reproduced by ten days in the Weatherometer). The ink samples may also be sent to a controlled humidity room, subjecting them to any conditions of humidity and temperature that might occur in pressrooms in any climate.

One of the most precise and valuable ink-lab instruments, the Inkometer, is a small machine with several rollers, enabling us to observe such working properties of ink as how it "tacks" or adheres to surfaces and rollers, and how solvent evaporation affects this tackiness or pull-resistance. In some of the better-equipped ink research laboratories, such studies may even be undertaken by means of high speed movies, with a camera taking 8000 frames per sec., revealing ink behavior in slow motion and in minute detail.

To make sure that the ink is free from pigment agglomerates which might clog a printer's plates, it is tested on a Grindometer, or fineness-of-grind-gage.

Inks for special surfaces such as plastic films, and for special end uses such as packaging, may be subjected to further testing. If a customer requires a heat-resistant ink for printing on a special plastic film that will be used to package soap powder, the control lab will print on the film, subject the printed sample to heat tests, alkali tests, soap resistance tests, and water resistance tests. Similarly, some inks must be acid-resistant, or odor free, or grease-resistant. As developments and discoveries are made every year in the graphic arts and packaging industries, printing inks are becoming more than ever "custom-built" products. Making printing ink becomes more and more like filling a doctor's prescription.

Printing inks are everywhere in our life. It is hard to imagine a world without the printed page, without newspapers, magazines, and books. It is hard to imagine our supermarkets and department stores without the colorful "personality" that printing ink has given to packages—the letterpress and offset inks on books and magazines; the flexographic inks on cellophane and plastic wrappers for meat, cheese, and vegetables; the gravure inks on cigarette packages and cartons; the vinyl inks on the decorated shower curtains; carton, bread-wrapper, and metal-decorating inks; inks for gummed labels, for kraft bags, for waxed milk containers; lithographic inks for record envelopes; the specially formulated inks for frozen food packages. It is hard to imagine our life without the "pageant of color" all around us. We live more than ever in a "showcase of printing ink."

O. C. Holland, Interchemical Corp. *Comment* 190.

Chlorine Degradation of Cellulose

Hercules Powder Co. announced it was releasing its U. S. patent 2,478,379 for free use by anyone.

This patent relates to a process of inhibiting cellulose degradation during chlorine bleaching in an aqueous acidic medium in the presence of free chlorine and a small amount of a nitrogen-containing compound, such as ammonia and amines, as the inhibitor.

Engraved Letterhead Contest

The winning entry for the best engraved letterhead contest was won by Grabados Fernando Fernandez, S.A., Mexico City, for Equipos Petroleros Nacionales, S.A., also

of Mexico City. The Mexican engraver was presented the Cronite Cup at the annual convention of the Engraved Stationery Manufacturers Association in Houston, Tex., this summer. It was the first time the award was won by an entrant outside the United States.

Nekoosa paper was the stock for the prize-winning entry.

Patent Abstracts

John C. Green, director of the Office of Technical Services, U. S. Department of Commerce, announces the publication by OTS of a new series of abstracts of patents owned by the Government which can be licensed at no charge by private firms and individuals for nonexclusive use. Published in seven booklets called *Supplement No. 2, Patent Abstract Series*, the abstracts describe patents released for licensing between July, 1955, and June, 1958.

"The abstracts furnish an idea of the essentials of an invention," Mr. Green explained. "If a person is interested in one of the inventions after studying the abstracts, he can then obtain a copy of the specifications by ordering a copy of the Letter Patent from the Commissioner of Patents for 25 cents. If he wants a license to use the patent, he addresses a request to the Government agency administering the patent as shown in the *Patent Abstract Series*."

Patents and Inventions

Inventors can now turn to a new information pamphlet, "Patents and Inventions—An Information Aid for Inventors" just published by the U. S. Patent Office, containing basic information on patenting and patent procedures, and related information which may prove helpful in the development and marketing of their inventions. Copies are available through the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., at a price of 15 cents per copy—$11.25 per 100 copies in larger lots—and the Department of Commerce Field Service Offices in cities where such offices exist. Also available at the same price—"General Information Concerning Patents" and "General Information Concerning Trademarks."

A. I. Ch. E.

The appointment of Larry Resen as chief editor of *Chemical Engineering Progress* (CEP) has been announced by F. J. Van Antwerpen, publisher of CEP and secretary of the American Institute of Chemical Engineers. Mr. Resen, who was refining editor of *Oil and Gas Journal* in New York for the past year, succeeds John B. Mellecker.

Paper Calculator

A circular type paper calculator for printers and other paper users is available for distribution from Eastern Fine Paper and Pulp Division, Standard Packaging Corp., Bangor, Me.

Giant Valves for Atomic Reactors

Crane Co. has been awarded three research contracts totaling $250,000 to develop giant valves for atomic reactors, it was announced by Thomas M. Evans, chairman.

The largest contract is $172,000 for a development program aimed at providing a high-temperature nuclear reactor system stop valve for a maritime helium-cooled reactor for surface vessel propulsion. The development program is a subcontract to the Electric Boat Division of General Dynamics Corp. which is the prime contractor to the Atomic Energy Commission and the Maritime Administration of the Dept. of Commerce.

The new merchant marine reactor will be designed to deliver 20,000 shaft horsepower—the same amount as America's first atom-powered merchant ship, *N/S Savannah*. However, with the new design, Crane engineers say the power will be delivered with a much higher thermal efficiency.

The *N/S Savannah* atomic power plant uses Crane main reactor stop valves, and operates on a pressurized water system at relatively low temperatures, much like the Navy's atomic submarine. The new helium-cooled reactor, coupled to a closed cycle gas turbine propulsion plant, will build the temperature up to as high as 1500°F. at a pressure of 1000 p.s.i.

A design study is for development of a reactor throttling valve for liquid-sodium cooled reactors. This study is being conducted for the Atomic Energy Commission as part of the sodium components development program which has as its purpose the development of reliable low cost components which will in turn reduce the cost of sodium-cooled reactor plants to the extent that they will be economic producers of electric power.

This throttling gate valve must be capable of handling molten sodium at temperatures over 1200°F. A completely new valve concept is being proposed to obtain a linear throttling characteristic. This will permit very accurate and precise flow control over a very wide set of flow conditions.

The giant valve needed for a power plant would be 14 ft. high, weigh 6000 lb., and end connections for a 20-in. pipe diameter—the largest of its type ever proposed.

Another design study order, from the Navy Dept., Bureau of Ships, is for a device to provide flexibility, within a very limited space, for steam piping between steam generators and turbines aboard naval nuclear power plants. The flexible unit is hermetically sealed and must be capable of accommodating the relative movement of the steam generator, turbine and piping system due to vibration and thermal expansion without creating excessive stresses.

Arthur D. Little

Arthur D. Little, Inc. opened an office in Zurich, Switzerland, early in November, Raymond Stevens, president, announced at the company's Cambridge, Mass., headquarters. Mr. Stevens described this as another step in the research company's international expansion program to serve U. S. industry with overseas interests.

Support for the move came from Lt. Gen. James M. Gavin, executive vice-president, upon his return from Europe, where he was a delegate to the first German-American Conference in Bad Godesberg. Gen. Gavin confirmed the need for informed assistance to U. S. firms participating in the growing transatlantic business activity.

In 1957 the Arthur D. Little Research Institute was established at Edinburgh, Scotland, to perform long-term basic research for U. S. and European industries and governments. That year the company also opened an office in San Juan, Puerto Rico, to handle research activities in the Caribbean area. Recently it completed industrial development programs for Northern Ireland, Norway, Iraq, and Egypt.

The new Zurich office is headed by Alexander Bogrow, who has been in charge of A.D.L. work in the economics of the petroleum and mining industries. He is being assisted by Richard A. Stephan, recently a member of the company's New York branch.

Fire Prevention

Two pamphlets—one dealing with home fires, the other with industrial fires—have been published by the National Safety Council.

The 12-page home pamphlet, "Before It's Too Late," is dedicated to "all the brave firemen who try to arrive before it's too late."

"One fire can wipe out everything you have—your home, your property, your family," the publication says. "All home fires can be prevented. Fires are man-made." An ideal off-the-job safety aid, according to the council.

"Fred Flame, the Fiery Delinquent" is a 16-page illustrated pamphlet that begins: "Fred Flame was born one morning at the McDoke Co. His mother was a fine fire, but his father was just trash. . . ."

A single copy of each pamphlet is available free from the National Safety Council, 425 N. Michigan Ave., Chicago 11, Ill.

Fire Prevention Handbook

A handbook on fire prevention and protection in industrial plants has been published by the Office of Technical Services, U. S. Department of Commerce. The manual was prepared by the Navy's Bureau of Yards and Docks for use of its personnel responsible for construction and maintenance of the Navy's shore installations.

Basic fire prevention measures are covered including requirements for construction, emergency and protective features, and safeguards against common hazards. Special fire hazards are also discussed. General storage criteria are set forth, as are various methods of inside and outside fire protection, such as extinguishing, detection, and alarm systems. One chapter covers the special problems of fire prevention and protection during construction.

In addition to the more common fire hazards discussed are special hazards such as chemicals and metals, welding and cutting, operations, surface finishes, plastics, electricity, flammable liquids and gases, oil burners, rocket fuel, dust explosion, and woodworking.

The publication, PB 151695 *Fire Prevention and Fire Protection,* Bureau of Yards and Docks, U. S. Navy, 190 pages, may be ordered from OTS, U. S. Department of Commerce, Washington 25, D. C., price $3.00.

Bronze Oscar of Industry

Dana C. Huntington, president of Dennison Manufacturing Co., Framingham, Mass., received a Bronze Oscar-of-Industry for the best annual report in the Paper Products Industry from Richard J. Anderson, editor and publisher of *Financial World,* at the Annual Report Awards Banquet held recently at the Astor Hotel in New York City.

The presentation of awards climaxed the 19th Annual Survey of Annual Reports conducted by *Financial World,* well-known investment and business magazine. More than 5000 annual reports were reviewed by the editors in the initial phase of the contest.

The Dennison organization previously was awarded a Bronze Oscar in 1943 for its 100th anniversary report. Since entering the *Financial World* competition, Dennison has won 16 consecutive Merit Awards.

Air Pollution Study Published

A translation by B. S. Levine, U. S. Public Health Service research grantee, of the Russian book "Sanitary Protection of Atmospheric Air: Purification of Industrial Discharge Gases from Suspended Substances" has been published for sale to the public by the Office of Technical Services, U. S. Department of Commerce. The book was written by V. N. Uzhov of the Technological Division of the Institute for Making Gas Purifying Equipment in Moscow.

Included in the 160-page volume are chapters on Properties of Gas Suspensions, Methods of Mechanical Gas Purification, Wet Gas Purification, Gas Filtration, Electrical Gas Purification, New Methods and Apparatus for Gas Purification, Combination Gas Purifying Apparatus, Flue Gases from Heat and Power Stations and Boiler Plants, Elimination of Ash from Flue Gases from Large Electric Power and Heat Centers, Removal of Ash from Boiler Plant Flue Gases, Purification of Emission Gases in Plants of Ferrous Metallurgy, Purification of Discharge Gases of Non-Ferrous Metallurgical Plants, Purification of Gases Discharged by Cement Plants, Purification of Gases Discharged by the Chemical Industry, and Purification of Ventilation Air from Dust.

59–21092 "Sanitary Protection of Atmospheric Air: Purification of Industrial Discharge Gases from Suspended Substances" may be ordered from OTS, U. S. Department of Commerce, Washington 25, D. C., price $3.00.

Dr. Levine's translation of the three-part Russian book "Limits of Allowable Concentrations of Atmospheric Pollutants," edited by Prof. V. A. Ryazanov in Moscow, is being printed and will be available from OTS about November 15. The three volumes, all of which appear under the same title, are: 59–21173 Book 1, 1952, 145 pages, $2.75; 59–21174 Book 2, 1955, 179 pages, $3.00; and 59–21175 Book 3, 1957, 152 pages, $3.00.

Paterson Parchment

Vegetable Parchment in Sterilization

Laboratory tests recently completed have proved the suitability of Patapar vegetable parchment (27-2T) as a wrapping material in the recently developed ethylene oxide sterilization process.

In a report to the Paterson Parchment Paper Co., Bristol, Pa., manufacturers of Patapar vegetable parchment, the Castle Co., Rochester, N. Y., stated that parchment tests were conducted in one of their standard laboratory Steroxo-Matic sterilizers. The tests were run under the Castle sterilization program which evaluates the best way to sterilize products of customers or suppliers.

The new sterilizing method is designed for use when the high temperature or humidity associated with steam or dry heat sterilization techniques would prove injurious to the materials being sterilized. Steroxcide gas is employed as the sterilizing medium. The lethal component of this gas is ethylene oxide which is known to kill all microorganisms. Steroxcide gas sterilizes at low temperatures (70°F.) and at low humidities (35% R.H.).

Hospitals use Patapar for wrapping surgical instruments, dressings, and other articles to be sterilized in the autoclave. In the preparation of Salk polio vaccine, pharmaceutical houses employ Patapar for wrapping glassware and other equipment prior to autoclave or dry heat sterilization.

Heat-Seal Parchment for Packaging

For packaging applications involving high wet strength, grease resistance, or direct wrapper contact with products of high oil content, the Paterson Parchment Paper Co., Bristol, Pa., has announced the introduction of Heat-Seal Patapar Vegetable Parchment.

Heat-Seal Patapar will function smoothly and efficiently on conventional automatic, heat-seal wrapping equipment, will transmit no foreign flavor to foods with which it comes in direct contact, offers excellent protection against water vapor transmission, and can be heat-sealed face to face or face to back.

Chlorine Manual

The Chlorine Institute, Inc. has just published a third edition of its "Chlorine Manual." The manual, considerably broader in scope than the previous editions, is intended to be a compendium of experiences available to the Institute, of materials, equipment, and practices that contribute to the safe handling, storage shipment, and uses of chlorine. Important properties of chlorine are included, as well as practical methods of dealing with emergencies that have been encountered. An extensive bibliography is included. Information regarding its availability can be obtained from The Chlorine Institute, Inc., 342 Madison Ave., New York 17, N. Y.

Container Corp.

Container Corporation of America has installed a new Swift corrugator and a Hooper printer-slotter in its new plant recently opened in Fresno, Calif.

The Swift corrugator is an 87-in. heavy duty machine capable of running 600 lineal f.p.m. The Hooper printer-slotter is a 35 by 78-in. machine. Both were furnished by the Container Machinery Dept., Metal Products Div. of Koppers Co., Inc.

KVP Sutherland Paper Co.

Committees appointed by the Board of Directors of KVP and Sutherland Paper Cos. both of Kalamazoo, Mich., have met and agreed in principle on the merger of the two companies. Each committee is recommending to its respective Board of Directors that the merger be approved. The new venture will be known as the KVP Sutherland Paper Co.

The exchange contemplated is one and two-tenths shares of common stock of the new company for each share of KVP and one share of common stock of the new company for each share of Sutherland.

When the proposed merger is approved by the Directors and Stockholders of both companies, it is contemplated that Dwight L. Stocker, president of KVP Co., will be named president and chief executive officer of the new company.

Finch, Pruyn

Company officials, members of the sales department, and department heads of Finch, Pruyn and Co., Inc. entertained about 60 of their paper distributors at open house at the pulp and paper manufacturing plant in Glens Falls, N. Y., recently.

Paper merchants, guests of Finch, Pruyn and Co., Inc., N. Y., at an open house at the plant recently

Guests were escorted in small groups on tours to view the various papermaking processes and to see the improvements in departmental equipment which have been made since the last merchant meeting.

Duplicator and Mimeo Bond

Finch, Pruyn has just announced that 16 and 20-lb. Finch Duplicator and Finch Mimeo Bond are now available in two larger sizes. The mill is now stocking both these papers in 17 × 22 and 22 × 34.

Clupak, Inc.

World Firms to Share Research on New Paper

A world-wide paper industry licensing program under which licensee paper companies will share with one another their research advances and technical known-how in the manufacture of Clupak paper is now being organized by Clupak, Inc., which owns the Clupak trademark and patents on the new flexible, tough and tear-resistant paper.

Details of the licensing program, which already includes Swedish and Canadian paper companies, as well as nine major American firms, were reported by Dudley B. Smith, manager of licensee services for Clupak, Inc., at a recent private seminar of the American Management Association in Chicago and have now been made public by the company.

Under the program:

1. Manufacture of Clupak paper, under quality standards set by Clupak, Inc. and under its trademark and patents, is open to any paper company throughout the world at a fixed royalty fee (payable in dollars); this fee is identical for every company and every country. Patents already have been filed in 35 foreign countries and the trademark Clupak is registered in over 50 countries.
2. Clupak, Inc. is making available information on its extensive research and technical know-how in manufacture of the extensible paper, and will transmit to every company under license, information on all advances by any other company in the field. Any licensee whose own research on the new type of paper yields new patents dominated by existing Clupak patents adds these new patents to those previously available to other licensees throughout the world.
3. Each paper company licensed to make Clupak paper may sell its product anywhere in the world in competition with other licensees.
4. Clupak, Inc. protects the Clupak trademark both legally and technically as to the quality of the Clupak paper produced; sends its technical men out to train personnel of the licensee company; helps licensees market, sell, and promote the use of Clupak paper, and sponsors extensive research and development projects.

St. Regis to Produce Clupak Paper

Production of Clupak paper by St. Regis Paper Co. has begun at the company's Pensacola, Fla., mill, it is announced by G. E. Amerman, president of Clupak, Inc.

The new paper will be made on the St. Regis' Pensacola no. 3, 212-in. wide machine, which has a production capacity of approximately 180 tons a day, and will be marketed under St. Regis' own trademark in conjunction with the Clupak trademark for use in multiwall sacks and converting kraft grades.

Other Clupak extensible paper units already in commercial operation are: West Virginia Pulp and Paper, International Paper Co., St. Lawrence Corp., Union Bag-Camp Paper Corp., Albemarle Paper Co., and Continental Can Co.

Continental Can Clupak Paper Production

At its Hodge, La., paper mill, Continental Can Co., Inc. has started production of Clupak paper, it is announced by G. E. Amerman, president of Clupak, Inc., the owners of the Clupak paper patents and the Clupak trademark.

Continental Can's new Clupak extensible paper unit has been installed on its no. 4, 246-in. wide machine, which has a production capacity of approximately 250 tons a day and will produce Clupak paper for general converting purposes, with special emphasis on multiwall sacks.

Rayonier

How to Handle Baling Wire

A new safety booklet, on the handling of baling wire published by cellulose and wood pulp producer Rayonier, is offered free of charge to the chemical processing industries, the paper industry, and others.

Included with the booklet is a smaller handbook on basic safety tips for cutting wire on pulp bales. Clearly illustrated, it is primarily designed for workers in shipping, receiving, and manufacturing departments. Both booklets were prepared by the cellulose producer's safety department under

the direction of Robert M. Gilmore, prominent safety authority and Rayonier safety director.

Copies are available on a first-come, first-served basis as long as the supply lasts. Write on company letterhead, stationery to Rayonier Inc., Sales Dept., 161 E. 42nd St., New York 17, N. Y.

Brown

Brown Co., northern New England pulp, paper, and other forest products manufacturer, has acquired a controlling interest in Resi-Chem Corp. of Swanton, Ohio, it was announced by Laurence F. Whittemore, Brown Co. board chairman.

Terms of the acquisition were not announced but the announcement stated Brown had acquired an additional 30% interest making it the holder of 80% of the common stock of Resi-Chem. Since March 27, 1956, Brown Co. has owned a 50% interest in Resi-Chem. The additional purchase was a cash transaction.

Howard A. Raymond, Jr., of Toledo, Ohio, will continue as president, Edward J. Romay of Maumee, Ohio, as vice-president of Resi-Chem Corp., and Stuart W. Skowbo, senior vice-president and treasurer of Brown Co., will continue as treasurer. All three are directors of Resi-Chem Corp.

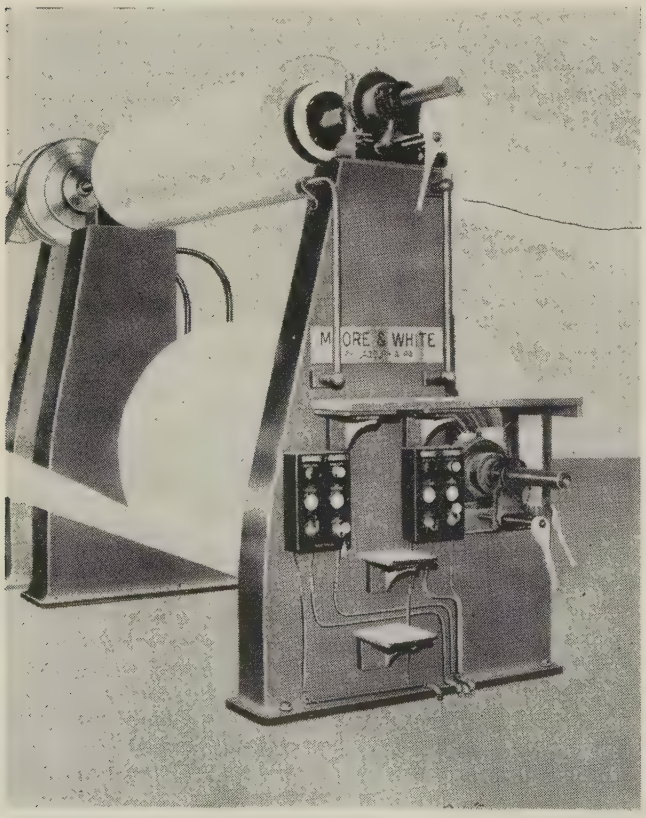
Resi-Chem Corp. is a producer of wet strength resins used in papermaking, adhesives used in the plywood industry and other fields, and synthetic resins in general.

Appointments

Alexander B. Walker of Gorham was elected assistant treasurer of Brown Co., Berlin, N. H., pulp paper, and forest products manufacturers.

Morris Paperboard

Morris Paperboard Co., Paterson, N. J., have increased their production and quality with a new Moore & White upright reel and new press section.



Moore and White upright reel

The reel allows Morris to handle rolls up to 60 in. without splice on rewind and a better control of the winding and rewinding tension. At the same time, Moore & White also installed a new third and fourth primary and first main press section on the Morris Machine. This sturdier, more accessible section with its pneumatic loading devices, enables the company to accurately control the loading of each press, and the machine requires less attention when operating.

Weyerhaeuser

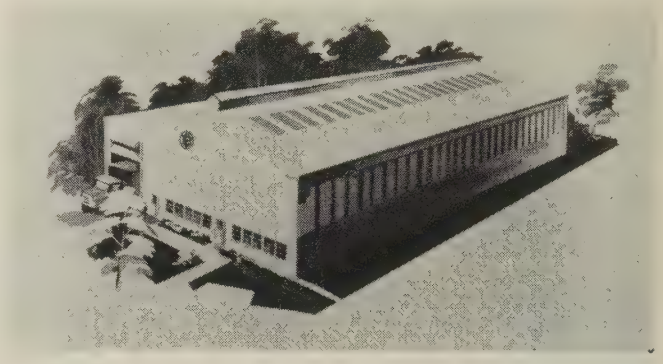
Cone Harvest

A record 190,000-bushel harvest of seed cones this fall was reported by Royce O. Cornelius, Weyerhaeuser Co. managing forester. The cones should yield about 100,000 lb. of seed for reforestation programs.

Hundreds of week-end cone collectors were paid $427,500 by Weyerhaeuser for their spare-time efforts. The record harvest compared with 3500 bushels in 1955, 43,000 in 1956. 30,000 in 1957, and 20,000 in 1958.

Black-Clawson Builds Research Laboratory

Black-Clawson Co., Middletown, Ohio, has begun the Construction of a research laboratory to be equipped to investigate every aspect of paper stock preparation and other papermaking operations. A specially designed building on the



New Black-Clawson research laboratory

plant site of Black-Clawson Co.'s Shartle Division will house the pilot plant stock preparation system, the wet testing laboratory, and the dry testing laboratory now located on the Dilts Division property in Fulton, N. Y. Space is provided for expansion for these facilities and extension of them into related pulping and papermaking operations.

St. Regis

St. Regis Paper Co. announces that Lone Star Bag and Bagging Co. of Houston, Tex., and Wagner Bag Co., of Salt Lake City, Utah, which it acquired recently, will continue operations as subsidiaries of St. Regis. These subsidiaries will result in the expansion of the product lines of St. Regis' Bag Division and provide it with a full line of flexible packaging materials for all types of bags and sacks.

In addition to multiwall paper bags, St. Regis will now produce and sell a full line of textile bags, including burlap, cotton, paper mesh, and paper-textile-film laminates. Also, St. Regis will distribute all types of film plastic bags.

As subsidiaries of St. Regis, both Lone Star Bag and Wagner Bag will continue with their present management. Wagner Bag is completing a new plant to house both textile and multiwall operations, as well as its offices. Multiwall production will cover the full lines of sewn bags and SOS pasted baler bags.

Cupples-Hesse Co.

Construction is nearing completion on the modern, new Des Moines plant of the Cupples-Hesse Co., a division of the St. Regis Paper Co.

The new plant, located at 1655 E. Madison St., will have 25,000 sq. ft. of floor space with additional land available for another 25,000-ft. expansion program. Production capacity will be increased to 1,250,000 envelopes daily. Additional envelope making machinery of all types will be installed in the near future.

Longview Fibre Co.

An agreement under which the Downing Box Co., Milwaukee, Wis., would become a part of the Longview Fibre Co. of Longview, Wash., a major West Coast producer of paper and paperboard and fiber containers, was announced by the presidents of the two firms. This agreement is subject to approval by the directors and stockholders of the two companies.

Dowing Box, founded in Milwaukee in 1918 by the late A. C. Dowing, has a plant at Cedar Rapids, Iowa, in addition to its main facilities in Milwaukee.

The 33-year-old Longview Fibre Co. operates a paper and paperboard mill at Longview and box plants at Longview; Seattle, Wash.; Los Angeles and Oakland, Calif., and has a wholly owned subsidiary, the General Fibre Box Co., at Springfield, Mass. The company has ownership of nearly a quarter million acres of timberlands. It produces paper and container board, containers themselves, and a wide variety of so-called paper and container board conversion products such as bags, towels, creped and treated papers.

Mead

Appointments

Lloyd W. Hale, assistant comptroller of The Mead Corp., has been transferred to Dayton from Chillicothe.

Paul E. Murray, staff accountant, Chillicothe, and Thomas J. Breshahan, resident accountant at Sylva, N. C., have been added to the Dayton staff of the comptroller.

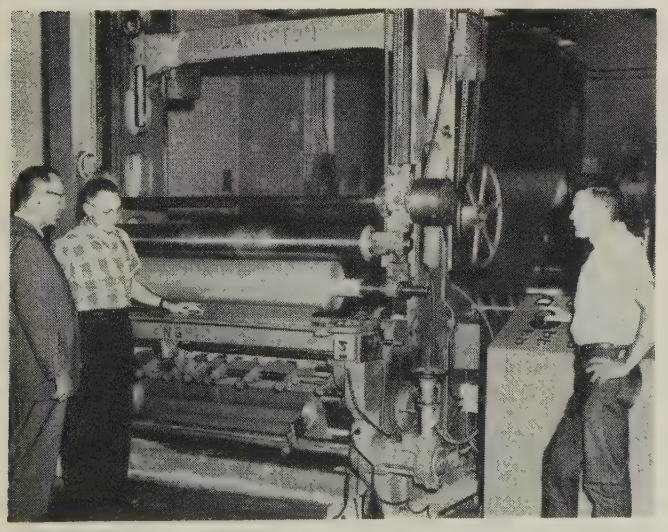
William H. Delavan announced recently that he was retiring as president of the Delavan Division of Mead Containers, Inc., subsidiary of Mead Corp.

According to W. J. Cassady, Jr. vice-president, of corporation, the duties and responsibilities of Mr. Delvan would be split between Paul H. Fulmer and Kenneth G. Foeppel.

Ecusta Paper

New Rewinder

A high-speed rewinder machine has been installed by Ecusta Paper, Pisgah Forest, N. C., it was announced by A. J. Loeb, division vice-president.



Ecusta's high speed rewinder

Equipped with many automatic features, the new rewinder is faster than earlier models and offers greater versatility in rewinding narrow-width rolls.

The machine, a product of the Langston Machine Co., Camden, N. J., handles the complete range of paper made at Pisgah Forest. It operates at a speed of 2650 f.p.m.—four times faster than earlier types of machines, and can be operated by one man only. A special feature is a hydraulically operated backstand which can be raised, lowered, or shifted from left to right.

Letterpress Paper

Development of a lightweight paper under 20 lb. for letterpress printing was announced by Ecusta Paper Products, Pisgah Forest, N. C., part of the Packaging Division of Olin-Mathieson Chemical Corp.

The paper, which has a basis weight of $17^1/_4$ lb. and uses a sulphate finish, is the latest addition to the Company's Waylite line of fine papers. It was developed, according to George W. McCleary, sales manager for fine paper, in response to demand from Bible and handbook publishers who have been using Ecusta's 20-lb. paper successfully.

Noralyn

Noralyn Paper Mills, Inc. of Baton Rouge, La., using not one single pound of coniferous fiber, has commercially produced hardwood newsprint with unique properties.

The Noralyn sheet has a photovolt brightness of 65 to 67 points and has been used on the regular press runs of the Milwaukee *Journal*, New York *Times*, and Savannah *Evening Press* at speeds up to 46,000 copies per hour without a single break. Strength tests, as reported by the Herty Foundation, show it to have strength equal to or better than all standard sheets with which it has been compared. Its opacity is excellent and for color printing it adds brilliance and contrast which are a marked improvement over softwood sheets.

On July 6 a contract was entered into by Noralyn's president, Leo L. Stack, and The H. K. Ferguson Co. of Cleveland, Ohio, for final design and construction of a plant to produce 350 tons per day of Noralyn newsprint on the company's site at Busche, La. The plant will be on the opposite side of the river from Baton Rouge where Noralyn Paper Mills, Inc. maintains its head offices at 818 Fidelity National Bank Building, Baton Rouge, La.

Oxford Paper Co.

Construction of an electrostatic precipitator designed to recover more than 38,000 lb. of salt cake per day will start soon at the Oxford Paper Co.'s plant at Rumford, Me.

Engineered and fabricated at the Metal Products Division of Koppers Co., Inc., Baltimore, Md., the precipitator is of the double-chamber type and is designed to handle 115,000 cu. ft. per min. of gas from a 300-ton recovery boiler.

Each chamber of the new unit will contain two fields, each 7.5 ft. long and 20 ft. high. The two chambers will be built side by side, giving an over-all width for the installation of 32 ft.

Specifications for the Oxford precipitator call for removal of 95% of salt cake held in suspension in gas from the recovery boiler. Based on a specified loading of 1.75 grains per cu. ft. of incoming gas this will mean the precipitator will be recovering four-fifths of a ton of salt cake every hour of operation.

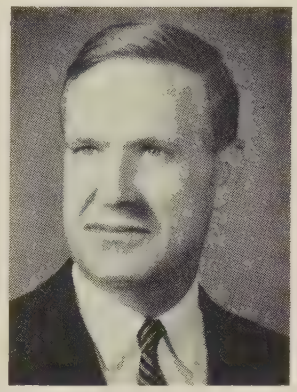
Courtaulds

Courtaulds Limited and its American and Canadian subsidiaries have formed jointly two new companies to seek and develop opportunities for expanding Courtaulds' activities in industries outside textiles, it was announced by Courtaulds North America Inc.

Courtaulds is a world-wide producer of man-made fibers and textiles and also manufactures chemicals, petrochemicals, packaging films and products, plastics, paint, and pulp. Courtaulds Ltd. has subsidiary and associated companies in 11 countries and is represented in 50 other countries.

Chesapeake

Reavis C. Sproull, of Richmond, research chemist and consultant, has been named director of research and development of The Chesapeake Corp. of Virginia, West Point, Va., according to an announcement by Erik Zimmerman, vice-president and production manager of the company.



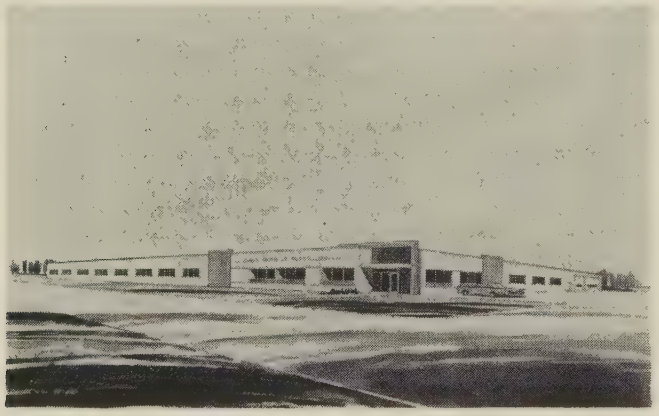
Reavis C. Sproull, Chesapeake Corp. of Virginia, West Point, Va.

Dr. Sproull has had 27 years of experience in teaching, research and development, and in laboratory management. For 7 years he was associated with Phillip Morris, Inc.—since April 1, 1956, in Richmond.

His broad responsibilities will be to develop new processes and new and improved products at the kraft pulp and paper mills, and to assure more complete utilization of the woodland resources of Chesapeake's operating area.

Sabin Robbins

Sabin Robbins, president, Sabin Robbins Paper Co., Cincinnati, Ohio, announces that increased demand for the company's quality job-lot printing papers will result in a new office-warehouse facility to serve Midwest printers and users



Sabin Robbins' new office-warehouse in Broadview, Ill.

of printing paper in the Chicago area. The new 60,000-sq. ft. building is under construction in Broadview, Ill.

Sabin Robbins Paper Co. is the world's largest and oldest job-lot printing paper supplier.

J. B. Card & Paper

The J. B. Card & Paper Co., one of New Jersey's oldest paper houses, has been named exclusive New Jersey distributor for New York & Pennsylvania Co.'s offset grade, "Penn/Brite," it was announced recently by officials of the latter company.

Continental Can

Continental Can Co. will double the capacity of its Los Angeles corrugated box plant next year when it completes the installation of equipment at a new location it has leased.

A one-story precast concrete panel building at 6400 E. Washington Blvd. has been leased by Continental. The new corrugated plant has an area of 213,000 sq. ft. and will be equipped with a Langston combiner which will produce a continuous sheet of corrugated paperboard, 85 in. wide, at a rate of 10 million sq. ft. a week on a two-shift basis. The new plant will be in full operation by March 1, 1960, and will employ 150 men and women.

Nashua

Development of IMAC ML-5 heat seal, a new and improved label paper for prepackaging meat, cheese, and other refrigerated products in the supermarket and packing plant, was announced this month by Nashua Corp. at Nashua, N. H.

The new heat-seal grade is activated at a temperature 16° lower than that required to activate label papers now available and is designed to eliminate losses due to damage of sensitive packaging films and products in the process of labeling. Trouble-free performance is assured on various types of high-speed automatic and semiautomatic equipment when the new grade is used.

When applied with proper heat and pressure ML-5 will give a paper tearing bond on Saran, Cryovac, Pliofilm, Cellophane, Aluminum Foil, and Saran Coated Cellophane.

Goodyear

Vita Film Production

A 50% expansion in Vitafilm production facilities in Akron, Ohio, was announced by The Goodyear Tire & Rubber Co.

President Russell DeYoung said that expansion was now under way at the subsidiary Goodyear Aircraft Corp.'s Akron Plant B, site of the parent company's manufacturing facilities for the heavy-duty packaging material.

Vitafilm was introduced originally as an industrial wrap, but new formulations approved by the Food & Drug Administration have expanded its uses into food fields.

Fibreboard

Fibreboard Paper Products Corp. has awarded the Metal Products Division of Koppers Co., Inc. a contract to furnish a Hopper printer-slotter for its new plant currently being built in Hawaii.

The plant will produce shipping containers for both fresh and canned fruits. The printer-slotter will be 50 by 103 in. and will be capable of running 200 sheets per minute.

Packaging Institute

Food Additive Problems

The complex and far-reaching effects on packaging of the 1958 Food Additives Amendment to the U. S. Food, Drug and Cosmetic Act have resulted in a decision by the Packaging Institute to organize a committee to study the subject. To be known as the Packaging Committee on Food Additive Problems, this group is expected to provide industry-wide and sustained attention to the vital problems involved in compliance with the Food Additives Amendment.

The launching chairmanship of the Packaging Committee on Food Additive Problems has been accepted by Roger V. Wilson, director of customer research, Metal Div., Continental Can Co. Official representatives of all of Packaging Institute's 400 corporate members have received letters inviting their companies to participate in the work of the committee. Although replies are still coming in, early returns indicate that the new committee will have across-the-board representation from the packaging industry, as represented by the Packaging Institute's corporate membership.

Folding Carton Commitee

Plans for organization of a Folding Carton Committee in the Materials Division of the Packaging Institute have been announced by L. H. Zahn of Ciba Pharmaceutical Products,

Inc., director of committee activities for the Institute.

Named launching chairman for the new group is Marshall Baldwin, general purchasing agent for packaging materials of the Household Products Division of Colgate Palmolive Co. A group of qualified specialists in the folding carton field, to serve as the nucleus for the proposed committee, will meet soon with Mr. Baldwin to define the goals and draw up a preliminary work program.

Broad objectives of the Folding Carton Committee will be to develop performance (use) standards covering most of the factors involved with this container.

Quality Control Course

The thirteenth annual short course in *Quality Control by Statistical Methods* will be offered by the Mechanical Engineering Dept., Univ. of Illinois, with the cooperation of the Division of Engineering Extension at Urbana from Feb. 1 through Feb. 11, 1960. Intensive work will be given in the fields of control charts and acceptance sampling with some attention paid to the rational setting of specifications and tolerances. It is designed for those in the areas of design, production, procurement, management, quality control, and inspection. For further information, write to Robert K. Newton, Supervisor, Engineering Extension, 116 D Illini Hall, Champaign, Ill.

Nuclear Research

Brookhaven National Laboratory

Thousands of visitors have once again streamed through this nuclear research center. Each year in October, the Laboratory holds a Visitors' Day, a High School Students' Day, and a College Student Visitors' Day. On these three days guided tours to the major research facilities are provided and the program includes special demonstrations, exhibits, lectures, and motion pictures.

BNL is a national research center for fundamental and applied research in the nuclear sciences and related subjects, and is a part of the nation-wide program of the Atomic Energy Commission. It is operated under contract by a private institution, Associated Universities, Inc., which comprises nine northeastern universities: Yale, Columbia, Princeton, Harvard, Johns Hopkins, Cornell, Rochester, Pennsylvania, and Massachusettes Institute of Technology.

At present over 1800 persons are employed by the Laboratory. Of these, 350 are scientists and 650 technical personnel. In addition, there are 200 other United States and foreign scientists and graduate students from universities, colleges, research institutions, or industry working at the Laboratory for short periods. During the summer, the Laboratory provides research and training opportunities for about 125 scientists and 100 students. Unlike the other laboratories of the AEC (Hanford makes plutonium, Oak Ridge, U^{235}, Los Alamos, bombs), Brookhaven "makes" nothing but knowledge; the specific application of that knowledge is left largely to others.

Today, over 98% of Brookhaven's research is unclassified, and most problems can be discussed freely, even with foreign visitors.

Research Activities

The Brookhaven research program is centered on the development and exploitation of nuclear science and technology and covers many subjects in the physical and biological sciences, and in engineering. Broadly classified, the activities fall into five categories: (1) fundamental studies of atomic nuclei, constituent particles, and forces involved in their structure; (2) study and exploitation of the physical, chemical, and biological effects of radiation (a 48-bed hospital accommodates those patients referred to Brookhaven by their own physicians for special observation or therapy); (3) the use of nuclear particles such as neutrons, charged particles, gamma-rays, and isotopic tracers in all branches of scientific research; (4) research and development of non-nuclear nature useful in atomic energy development; (5) useful applications of nuclear power.

Research Facilities

To pursue the Laboratory research objectives scientists have at their disposal a nuclear reactor as well as a massive array of particle accelerators.

The Reactor. The Reactor proper consists of a 25-ft. graphite cube separated into two halves by a 2.75-in. gap. Sixty thousand graphite blocks, with a total weight of 700 tons, make up the core, which contains 1368 round, parallel fuel channels spaced 8 in. between centers. The graphite cube and air chambers are enclosed in a 5-ft. thick shield of high density concrete.

By using only 57 g. of enriched U^{235} as fuel, it is possible to obtain a central neutron flux of 2.5×10^{13} per sq. cm. per sec. at an operating power level of 16 Mw. About 300 items are made radioactive in the reactor each month. Half of the material is used for studies by BNL scientists, and the other half is sent to research institutions, including hospitals.

Liquid Metal Fuel Reactor. The LMFR has been under investigation at Brookhaven for several years. Results have shown that in such a reactor, highly enriched uranium dissolved in molten bismuth, together with zirconium and magnesium as corrosion inhibitors, can be used as a liquid fuel with graphite as a moderator.

This type of reactor offers many advantages over the solid-fuel type. Used for the production of electric power, it could provide an over-all efficiency of about 40%, which compares favorably with that available in most modern conventional steam plants. Design of the LMFR is now beyond the bench-scale stage.

Particle Accelerators

These machines accelerate electrically charged particles, such as protons and electrons, to high speeds in electric fields.

The Cosmotron. The largest operating accelerator at Brookhaven is a proton synchrotron called Cosmotron because it gives protons an energy of 3 billion electron volts (3 Bev), comparable to the energy of some cosmic rays. It is shaped in the form of a doughnut with the electromagnet 75 ft. in diameter.

In 1952 the Cosmotron was the world's most powerful accelerator but was soon outpaced by the University of California's Bevatron (6.2 Bev). In April, 1957, the giant synchrophasotron, at the Dubna Laboratory in Russia, reached an energy of 10 Bev. The steel requirements for the magnets of this machine were 36,000 tons.

Alternating Gradient Synchrotron. Using the strong focusing principle, the AGS will accelerate protons to an energy of more than 25 Bev. The machine will have a circumference of about 0.5 mile and will be housed in an underground tunnel. The particles will be kept in their circular orbit by means of 240 strong focusing magnets requiring only 4000 tons of steel. This is $1/9$ the amount in the Russian 10-Bev machine and $2/5$ that in the 6-Bev Bevatron. The new synchrotron is scheduled for testing in 1960.

Forest Products

The Forest Products Laboratory, Madison, Wis., has announced the publication of the following reports: "Outdoor Exposure of Container-Grade Paper-Overlaid Veneers," Report No. 2151; "A Method for Rapid Measurement of the Rate of Decay of Free Vibrations," Report No. 2154; "Torsion of Rectangular Sandwich Plate," Report No. 1871; "Simply Supported Sandwich Beam—A Nonlinear Theory," Report No. 2157; "Groundwood and Chip Groundwood Pulping and Papermaking Experiments on Ponderosa Pine," Report No. 1947 (Revised).

Single copies of these reports are available free upon request

from the Director, Forest Products Laboratory, Madison 5, Wis.

Information on 21 species of eastern oaks is contained in a revised leaflet of the American Woods series published by the Forest Service, U. S. Department of Agriculture. Revised in September, 1959, this leaflet is available for 15 cents from the Superintendent of Documents, U. S. Printing Office, Washington 25, D. C.

Annual Review of Halogenation Reprints

Bound volumes of reprints of Dr. Earl T. McBee's "Annual Review of Halogenation" covering the past 10 years have been published by the Columbia-Southern Chemical Corp. for distribution to scientists in the academic and industrial fields.

Copies of these bound reprints can be obtained by writing to the Columbia-Southern Chemical Corp., One Gateway Center, Room 2089, Pittsburgh 22, Pa.

Paper Industry Career Guidance

Two representatives of the National Paper Trade Association, Inc., have been appointed to serve on the Paper Industry Career Guidance Committee, it was announced recently by Floyd H. Blackman, NPTA president.

Arnold Posner, president, S. Posner Sons, Inc., Brooklyn, N. Y., and Lawrence E. Witte, NPTA's director of public relations, will represent the NPTA on the committee.

The committee was recently organized jointly by APPA, PIMA, and TAPPI to develop and promote the career guidance programs of the pulp and paper industry. Ward B. Morehouse, vice-president, Nopco Chemical Co., Newark, N. J., is committee chairman.

Objective of the committee is to attract and guide young people toward careers through materials and programs designed to acquaint them with the opportunities in this industry and to encourage everyone in the industry to use the committee's services, distribute materials it produces, and participate in its programs.

Diamond Alkali to Aid Education Program

The Diamond Alkali Foundation announced recently the establishment of a new, fourfold program designed to financially assist higher education in this country. The program, which becomes effective Jan. 1, 1960, includes direct financial grants to colleges, merit scholarship awards, graduate fellowships, and for the first time, an employee gift matching plan.

A significant part of the total contribution will be allocated for the educational grants program. Schools whose scientific curricula include courses beneficial to the chemical industry will receive the grants directly, and administer them at their discretion.

Under the merit scholarship program, the foundation will award two 4-year scholarships to students whose intended course of study pertains to the chemical industry. Finalists in the testing competitions of the National Merit Scholarship Corp. will be selected, with preference given to sons and daughters of Diamond employees.

Three graduate fellowships to students in the fields of chemistry and chemical engineering will be granted to different colleges and universities where, because of the type of work being done and the mutual interest of faculty and the company, there is a feeling of common benefit.

The employee gift matching plan is designed to encourage individual responsibility to higher education. The company will match contributions, up to $500 per year, of any regular employee to 4-year degree-granting schools, technical institutes approved by the Engineer's Council for Professional Development, and junior colleges whose credits are transferable to a regionally accredited 4-year, degree-granting school.

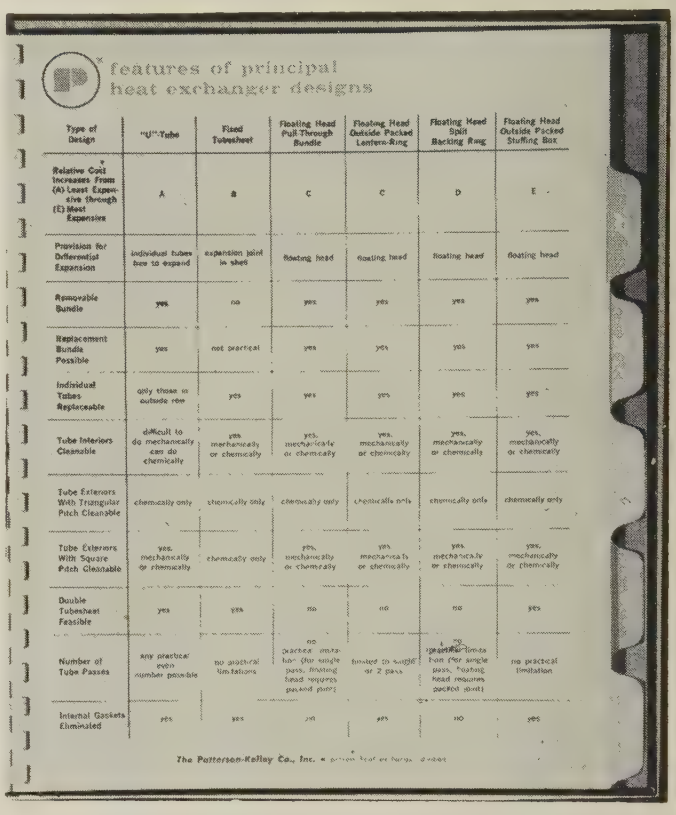
Additional information concerning these programs is available by writing to Diamond Alkali Co., Public Relations Dept., 300 Union Commerce Building, Cleveland 14, Ohio.

Patterson-Kelley

Heat Exchangers

Patterson-Kelley Co., Inc., one of the world's leading heat exchanger manufacturers, has published a comprehensive manual aimed at pioneering a standard approach to the identification and specification of heat exchangers.

The manual sets up a numerical and color-coded index system which is both functional and visually easy to use. The application of color to the detail drawings of the front and rear head components, for example, immediately brings out the differences in designs between these closures. With

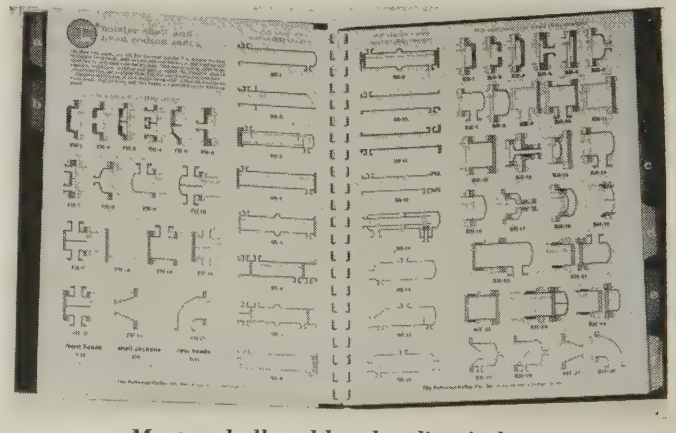

features of principal heat exchanger designs

Type of Design	"U"-Tube	Fixed Tubesheet	Floating Head Pull-Through Bundle	Floating Head Outside Packed Lantern-Ring	Floating Head Split Backing Ring	Floating Head Outside Packed Stuffing Box
Relative Cost Increases From (A) Least Expensive through (E) Most Expensive	A	B	C	C	D	E
Provision for Differential Expansion	individual tubes free to expand	expansion joint in shell	floating head	floating head	floating head	floating head
Removable Bundle	yes	no	yes	yes	yes	yes
Replacement Bundle Possible	yes	not practical	yes	yes	yes	yes
Individual Tubes Replaceable	only those in outside row	yes	yes	yes	yes	yes
Tube Interiors Cleanable	difficult to do mechanically can do chemically	yes, mechanically or chemically	yes, mechanically or chemically	yes, mechanically or chemically	yes, mechanically or chemically	yes, mechanically or chemically
Tube Exteriors With Triangular Pitch Cleanable	chemically only	chemically only	chemically only	chemically only	chemically only	chemically only
Tube Exteriors With Square Pitch Cleanable	yes, mechanically or chemically	chemically only	yes, mechanically or chemically	yes, mechanically or chemically	yes, mechanically or chemically	yes, mechanically or chemically
Double Tubesheet Feasible	yes	yes	no	no	no	yes
Number of Tube Passes	any practical even number possible	no practical limitations	no practical limitations for one single pass, floating head requires packed joint	limited to single or 2 pass	no practical limitations for one single pass, floating head requires packed joint	no practical limitation
Internal Gaskets Eliminated	yes	yes	yes	yes	no	yes

The Patterson-Kelley Co., Inc.

Features of principal heat exchanger designs

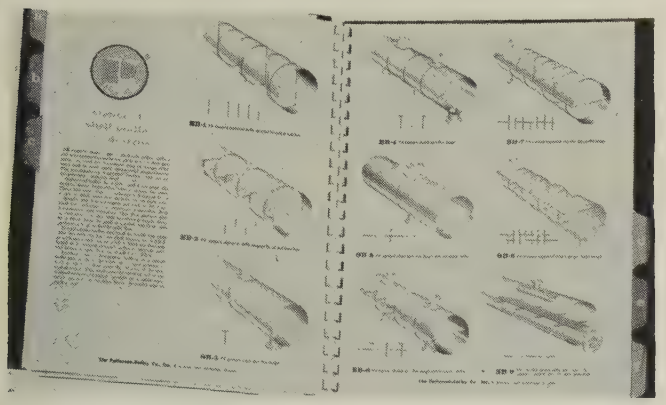
this coding, any combination of basic design and components can be arranged to meet design requirements, permitting those charged with the specification and purchase of equipment to identify and consider bids and to evaluate competitive quotations. Economics of selection—as a matter of mechanical design—is covered thoroughly and in order of "least expensive



Master shell and head coding index

to most expensive" for every component covered in the manual. The heart of the manual illustrates and explains the master coding index—a compilation of 17 front head, 16 shell

section, and 28 rear head designs—which, according to P-K engineers, "can produce 99 + % of all shell-and-tube heat exchangers manufactured today."



Standard shell baffle (SB) designs

All standard designs for gasket joints (including a novel charted description, recommended gasket material, usual application, and pertinent remarks) are defined and illustrated. Standard designs for flange facings and flange joints, tube to tubesheet joints, tube pass partitions, nozzle orientations, baffle arrangements (with two pages of fine-line drawings for visual aid in baffle identification), supports, and mountings are covered in a similar manner.

Primarily intended for a standard approach to "popular" or general types of shell-and-tube heat exchanger designs, the manual does not detail the complicated or "special" designs which—as pointed out by P-K engineers—must be left to the manufacturer. The more rigid the user's specifications, the less freedom the manufacturer has in incorporating his experience and knowledge.

The service-oriented manual (it can be used as an intra- or intercompany method of communication) is an actual workbook which provides design and specification assistance to those personnel working on the over-all standardization of the product.

The manual—titled "Heat Exchangers" and designated as Manual 700-A—may be obtained without cost by personnel involved in heat exchanger design and selection on request (use company letterhead and job title), or at cost, by writing to: The Patterson-Kelley Co., Inc., East Stroudsburg, Pa.

Cyanamid

Appointments

William F. Furcht is now technical representative of Cyanamid's paper chemicals department in New England.

Prior to his new appointment, Mr. Furcht served in the company's research laboratories at Stamford, Conn., where he was engaged in research and development work in the paper chemicals field.

A graduate of the University of New Mexico and New Mexico Highland University, Mr. Furcht holds a B.S. in biology and an M.A. in chemistry. His professional affiliations include membership in the American Chemical Society and the Technical Association of the Pulp and Paper Industry.

Peter J. Fitzpatrick has been appointed technical representative of American Cyanamid Co.'s paper chemicals department in the South Atlantic area. He will make his headquarters in Charlotte, N. C.

Acrylonitrile Modified Cellulose

According to American Cyanamid Co., acrylonitrile is being used commercially to modify the end properties of paper pulp. By a cyanoethylation process, acrylonitrile is added to the pulp stage to modify the cellulosic structure. The modified or cyanoethylated paper product forms the base of a new Permalex insulation system developed by General Electric for its line of pole-type distribution transformers.

Made from a cyanoethylated kraft pulp, the paper makes possible a 20% additional increase in peak load capability of transformer ratings with no sacrifice in life expectancy. Improved paper properties include greater resistance to deterioration by heat and prolonged retention of dielectric and tensile strength.

Stein Hall

Appointments

Stein Hall & Co., Inc. announced the election of Roger B. Sammon of Toronto as president of its Canadian subsidiary, Stein Hall Ltd., Toronto.

In a shift of top officers, David McGill, former president, becomes chairman of the board of directors, Mr. Sammon moves into his new position from that of vice-president, and vice-president Robert Strasser of New York becomes execu tive vice-president.

Roger B. Sammon, Stein Hall Ltd., Toronto

Pennsalt

Pennsalt Chemicals Corp. will complete the first phase of a $6 million modernization program of its Wyandotte, Mich., chlorine-caustic soda facilities before the end of this year, it was announced recently by Hugh C. Land, general manager of Pennsalt's Industrial Chemicals Division. The first section of improvements, now nearing completion, includes new 50% caustic soda evaporating facilities designed to reduce costs and improve quality.

The second major phase will be the replacement of several thousand Gibbs diaphragm-type electrolytic cells with a much smaller number of 30,000-amp., more economic cells, along with improvements to auxiliary cell-room equipment. When the new cells go on stream in mid-1960, the facility is expected to produce chlorine and caustic soda with product quality and operating efficiency equal or superior to any existing diaphragm cell operation.

Stowe-Woodward, Inc

Stowe-Woodward, Inc. announces that its Griffin, Ga., manufacturing division is currently processing suction press roll covers for southern paper mills. According to P. J. Mitchell, plant manager at Griffin, it is the first time that the covering of suction press rolls has been made available to southern mills from a southern plant.

Ames-American

After 90 years in the same location, Ames-American Co. of Woonsocket, R. I. (formerly American Wringer Co.) plans to move its plant from Woonsocket to North Easton, Mass., in the near future.

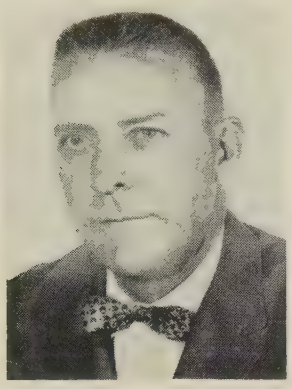
The company manufactures rubber-covered rolls for the paper, textile, plastic industries, and for miscellaneous industrial users.

The North Easton plant is a modern one-story building, 600 ft. long, owned by Ames Shovel and Tool Co., the parent company of Ames-American. The building is located on the N. Y., N. H. & H. Railroad for convenient rail shipments. For truck deliveries, it is one mile from Route 138, 25 miles from Boston and Providence, and 4 miles from Brockton and Stoughton, Mass.

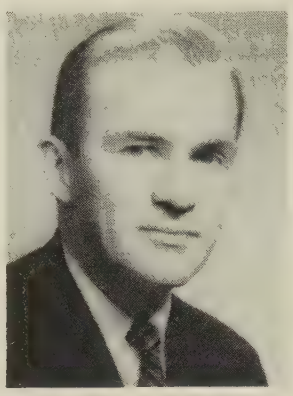
MIEHLE-GOSS-DEXTER

Appointments

John DeFoe has been appointed a sales representative in the Southeastern territory for the Miehle, Dexter and Lawson divisions. Miehle-Goss-Dexter, MGD., Inc., is the world's largest manufacturer of machinery for the graphic arts industry. Mr. DeFoe will report to F. L. Bryant, manager of MGD's Atlanta office and will cover the states of Tennessee, Alabama, Mississippi, and portions of Louisiana.

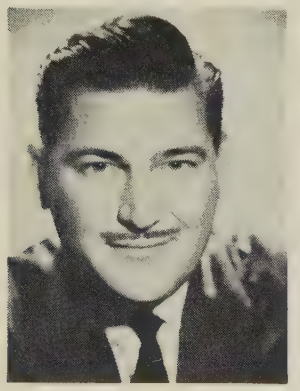


John DeFoe, Miehle, Dexter and Lawson divisions, Miehle-Goss-Dexter, Inc.

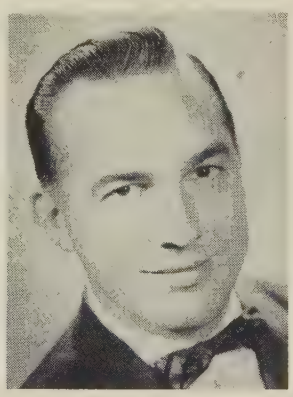


F. I. Walsh, Jr., Dexter Co., Division of Miehle-Goss-Dexter, Inc.

The appointment of F. I. Walsh, Jr., to the newly created post of vice-president and general manager of the Dexter Co., Division of Miehle-Goss-Dexter, Inc., was recently announced by J. E. Eddy, chairman of the board of MGD. He will make his headquarters at the Dexter plant in Pearl River, N. Y.



Sam H. Fitzpatrick, Miehle-Goss-Dexter, Inc.



Frank Janik, Miehle Co., Division of Miehle-Goss-Dexter, Inc.

Sam H. Fitzpatrick has rejoined Miehle-Goss-Dexter, Inc. as a sales representative handling MDL products in the San Francisco area after a year and a half leave of absence, according to a recent announcement by G. W. Bassett, sales manager.

Frank Janik has been promoted to product service manager of the Miehle Co., Division of MGD, Inc.

NATIONAL LEAD

Appointments

Titanium Pigment Corp., a subsidiary of National Lead Co., has announced the appointment of two new sales representatives for the New York and Cleveland sales districts.

Charles L. Novak will be affiliated with the New York sales staff in New York City.

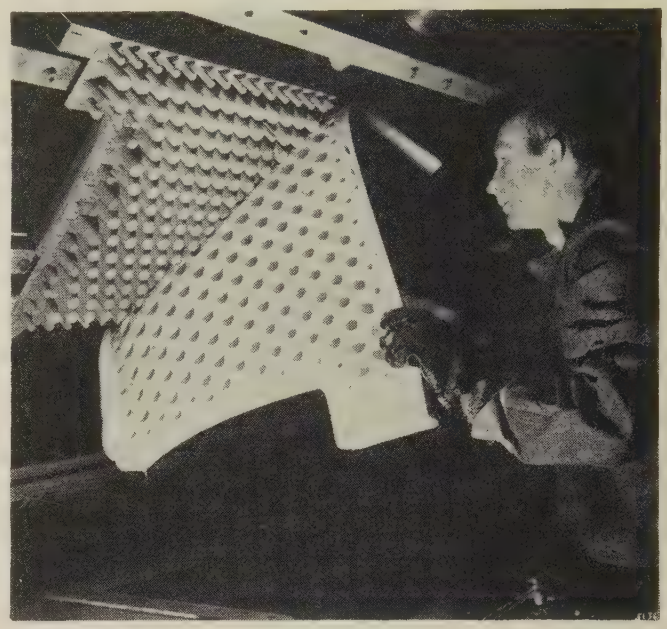
Thomas T. Wisner will join the North Central sales staff and will serve the Cleveland area.

GOODYEAR

New Synihetic Rubber Latex

Development and volume production of a new synthetic rubber latex as a 100% replacement for natural latex in foam rubber was announced recently by the Goodyear Tire & Rubber Co.

The company's Foam Products Division also announced that it is converting entirely to the new latex in the manufacture of airfoam cushioning materials.



Pliolite 5352 molded Airfoam cushion

The new latex—called Pliolite 5352—is capable of producing a foam rubber to meet the high cushioning standards set by automotive, furniture, mattress, and other manufacturers without blending in natural or other synthetic latices; it will be marketed to foam manufacturers at 20 to 30% under the natural latex price.

REMINGTON RAND

Electronic Computer

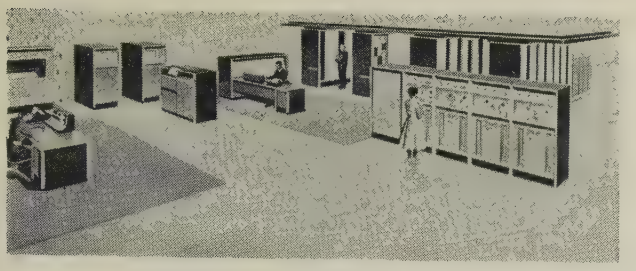
The availability of the world's fastest and most advanced electronic computer system for business and scientific use has been announced by the Remington Rand Univac Division, Sperry Rand Corp.

The new system, known as the Univac Larc Solid-State Computer, is a large-scale, "solid-state" digital computing system which can operate at speeds up to 200 times faster than any computer in existence today. It was originally designed and constructed by Remington Rand for the Atomic Energy Commission for their use at Livermore, Calif.

The Univac Larc can perform 250,000 additions or subtractions of 12-digit decimal numbers per second. It will enable business management to process problems 25 to 200 times faster than on existing computers. The rate of speed will depend on the problems being run.

The new computer will sell at upwards of six million dollars, and will rent from $135,000 a month. In terms of actual expenditure, the Univac Larc will cost appreciably less per operation than any other computer on the market.

The new system is capable of an unparalleled high-speed "memory" storage capacity. Magnetic core units store up to 97,500 words, while new high-speed drums store up to



The Univac Larc solid-state computer

6,000,000 words. These are supplemented by the enormous storage capacity of up to 40 magnetic tape servos.

The Larc consists of a main computer unit which works in conjunction with a second computer, called a processor. This allows the main computer to devote the major part of its time to the computing of problems instead of directing the various flows of information throughout the system.

The processor operates independently on its own program, upon signals periodically received from the main computing unit. The design philosophy of the processor calls for individual synchronizers to control all input and output operations. This makes it possible to have complete flexibility in the selection of input-output devices to be used. Data can be transferred at the rate of 400,000 decimal digits per second.

For greatly increased computing capacity, a second computing unit may be added. Except for certain intercommunication facilities, the computing unit and the input-output processor operate independently.

A typical installation comprises one computing unit, one processor, eight core memory units, twelve drum files, four tape units, and operator and engineer consoles.

A system originated by Remington Rand, known as Flow-Matic coding, which uses English words and phrases instead of mathematical symbols, will be adapted for use with the Larc.

La Motte

Wide Range Q.A.C. Test Set

A wide-range outfit designed for determining concentration of quaternary ammonium compounds in the range of 1.0 to 500 p.p.m. and above has been introduced by the La Motte Chemical Products Co. The lower readings are made directly and the higher readings require a dilution step with equipment provided for this purpose. The color standards are mounted in a special plexiglas viewing device that provides easier comparisons and eliminates the handling of individual standards. Sufficient material is furnished for making approximately 200 determinations. This light weight unit (3 lb.) is furnished in a rugged carry case for field use.

Manufactured by the La Motte Chemical Products Co., Chestertown, Md., this Model AC unit is priced at $25 each.

Allis-Chalmers

Valley Iron Works Corp.

The Valley Iron Works Co. of Appleton, Wis., has become the Valley Iron Works Corp., a wholly owned subsidiary of the Allis-Chalmers Manufacturing Co.

Motor Control Digest

A new 162-page digest with descriptive, pricing, technical, and engineering information on its complete line of motor controls has been prepared by Allis-Chalmers.

Copies of "Allis-Chalmers Motor Control" are available on request on company letterhead from Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.

Equipment Catalog

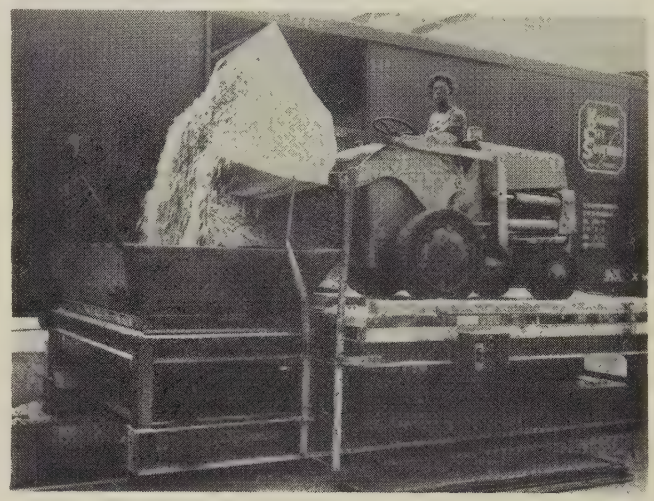
A catalog guide offering quick facts on Allis-Chalmers products for the pulp and paper industry has just been released by the company.

Equipment covered includes pumps, liquid heating system, water conditioning units, motors, controls, bark, chip and pulp screens, kilns, kiln chain, slakers, car shakers, switchgear, transformers, substations, and material handling machinery.

Copies of "Allis-Chalmers Equipment for Pulp and Paper," 25C6724L, are available on request from Allis-Chalmers, Milwaukee 1, Wis.

TractoLoaders

Use of front-end wheel loaders has increased by 30% the rate at which saw-mill chips are unloaded at International Paper Co., Spring Hill, La. About 250 cords of chips are unloaded daily. On the average, 100 cars are unloaded weekly.



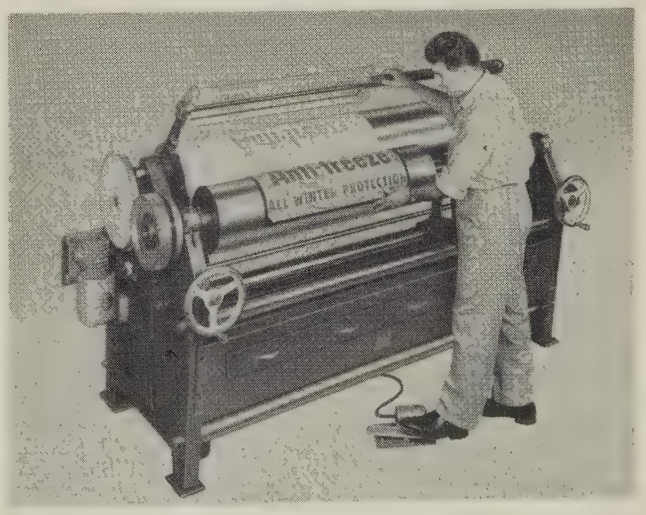
Allis-Chalmers' front-end wheel model TL-6 Tracto-Loader

The railroad cars pull up beside an unloading dock equipped with a hopper. The wheel loaders scoop up the chips, turn in extremely confined quarters, and dump their load directly into the hopper. The hopper is directly over a conveyor belt that leads to the wood room where chips receive initial processing.

Mosstype

"Mounter-Proofer"

A new improved version of its extended-range "Mounter-



Mosstype's "series M-5 Mounter-Proofer"

Proofer" machine for precision off-press setting up and proofing of large repeat rubber plate jobs, has just been introduced by Mosstype. Known as the "Series M-5 Mounter-Proofer," the machine is specially designed for printing repeats over 36-in. and can be supplied to accommodate plate cylinders up to 100 in. face width and 72 in. repeat.

The new "Series M-5 Mounter-Proofer" can be used with shaftless cylinders, "D-Mounts," or integral plate cylinders. When fitted with a dummy cylinder, it can be used for mounting plates on flexible carrier or draw sheets.

Further details about the "Series M-5 Mounter-Proofer" are available from Mosstype, Waldwick, N. J., or Elk Grove, Ill.

Rubber Plate Wash

A new nonflammable, nontoxic preparation for cleaning and conditioning rubber printing plates has been introduced by Mosstype Corp.

"Mosstype Rubber Plate Wash" facilitates the removal of both fresh and dry caked ink, finger marks, grease spots, and other soil. At the same time it imparts a velvety texture to the surface of the plate which improves its ink receptivity.

Additional information about "Mosstype Rubber Plate Wash" may be obtained from Mosstype, Waldwick, N. J.

M. W. Kellogg

Research and Development Service

A research and development service for companies seeking to develop new commercial processes was introduced recently by The M. W. Kellogg Co., New York, a subsidiary of Pullman Inc. The R & D service will be made available on a cooperative, contract basis. Its objective is to provide the reliable data that engineers need to design full-scale commercial plants, and to obtain research results with speed and at low cost.

Alex G. Oblad, Kellogg vice-president in charge of research and development, formally introduced the service stating that compensation will be based on an evaluation of the commercial applicability of a process, rather than on time spent or service performed.

Dr. Oblad cited successful cooperative research and engineering development projects Kellogg has handled in the past for industries including petroleum refining, chemical, iron ore, copper refining, paper, and pulp and food.

A 17-min. color film amplified and expanded the philosophy and services outlined by Dr. Oblad.

Distribution of the film, "Research and Development at M. W. Kellogg," will be Kellogg's first step in introducing their R & D to industry. Companies interested in exploring these services may borrow prints of the film by writing Research and Development, The M. W. Kellogg Co., 711 Third Ave., New York 17, N. Y.

Monsanto

Metal Oxides

Monsanto Chemical Co's. Research & Engineering Division is now making available to industry samples and technical data on a series of microfine metal oxides which it has trademarked Micria.

Four of the new products available in development quantities are: Micria AD and Al (aluminas), Micria TIS (titania), and Micria ZR (zirconia).

Suggested uses for the various oxides include catalyst carriers, polishing agents, organic dye stabilizers, whiting agents, thermal insulators, flow agents, solvent thickeners, and reinforcing agents. The metal oxides can be used also to impart opacity to superior grade paints, papers, and enamels.

Additional information can be obtained from Monsanto Chemical Co., Research & Engineering Div., development dept., 800 N. Lindbergh Blvd., St. Louis 66, Mo.

Lehigh

New Synthetic Oil

Lehigh Chemical Co. of Chestertown, Md., has developed a special synthetic oil with properties suitable for hydraulic type operations. Anderol L-386 is a medium viscosity, synthetic diester with an operating temperature range of −65 to 350°F.

For additional information or ordering, write direct to Lehigh Chemical Co., Industrial Lubricant Div., Chestertown, Md.

Reichhold

Robert J. Young has been appointed credit manager at the Reichhold Chemicals, Inc. executive offices.

Food Machinery

Phosphorus Output Expands

The Mineral Products Division of Food Machinery and Chemical Corp., one of the largest producers of phosphorus-based chemicals, has announced a major expansion in production of their Pocatello, Idaho, phosphorus plant.

Elemental phosphorus from Pocatello is shipped to FMC's plants in Lawrence, Kan.; Newark, Calif.; and Carteret, N. J., where it is used to produce a broad line of industrial, food and detergent grades of sodium and potassium phosphates, food grade, technical and agricultural phosphoric acid, and other phosphorus-based chemicals.

Conveyor Belt Service

The organization of a new Conveyor Belt Service, Inc. operation in Cleveland, Ohio, has been announced by William A. Mars, president of Conveyor Belt Service, Inc., Duluth, Minn.

The new company will be known as Conveyor Belt Service, Inc., of Ohio. The firm will provide eastern industrial operations with a repair and reconditioning service for conveyor belting, identical with that provided by Conveyor Belt Service, Inc. of Minnesota. CBS, Inc., operates its plant in Virginia, Minn., and has offices in both Virginia and Duluth.

Officers of the new Company are W. A. Mars, Duluth, president; James C. Heintz, Cleveland, vice-president; and R. S. Mars, Jr., Duluth, secretary.

The Ohio plant is located at 13110 Enterprise Ave., Cleveland. It is expected to be in operation some time before the first of the year.

The Central States Industrial Supply Co., headed by Raymond E. Britt, Cleveland, will serve CBS, Inc., as exclusive sales representatives in the Cleveland area. Central States Industrial Supply Co., a rubber products distribution company, was organized in 1946 and serves Ohio and parts of Pennsylvania. The company's offices are at 535 Terminal Tower Building in Cleveland.

Rohm & Haas

Appointments

Rohm & Haas Co., manufacturer of chemicals and plastics, recently announced the appointment of John C. Haas as director of purchases and traffic.

Mr. Haas has been serving as vice-president in charge of industrial relations. In his new assignment, effective October 19, he succeeded Peter J. Clarke, former director of purchases, who died on September 17.

Procter & Gamble

Appointment

Procter & Gamble recently announced the election of E. A. Snow, formerly manager of the advertising department, to the position of vice-president—advertising.

NORTON INTERNATIONAL

The corporate name of Norton Behr-Manning Overseas, Inc., has been changed to Norton International Inc., according to A. Donald Kelso, president.

The corporation itself has not been changed in any way. It will continue to operate the firm's 16 plants in 10 countries and to handle export sales of products made by Norton Co., Worcester, Mass., and its Behr-Manning Division, Troy, N. Y.

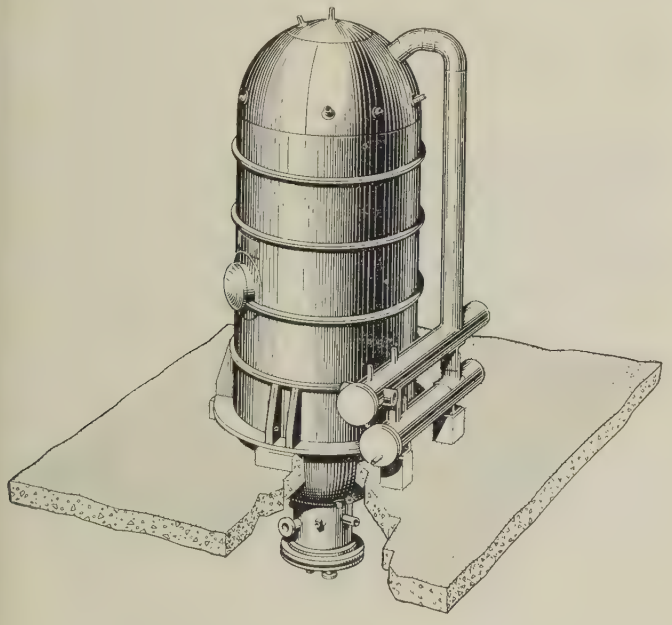
Norton and Behr-Manning products include abrasives, grinding wheels, coated abrasives, precision machine tools, high temperature refractory products, pressure-sensitive tapes, wear-resistant products, and pulpstones.

CHICAGO BRIDGE & IRON CO.

Radioactive Waste Concentrator

A new evaporator has been designed for concentrating radioactive wastes to be disposed of by Consolidated Edison Co. of New York, Inc., after its new 275,000-kw. Indian Point nuclear power plant on the Hudson goes into service in April, 1961.

Designed by Chicago Bridge & Iron Co., and currently under construction at its Greenville, Pa., shops, the evaporator will be made entirely of Inconel (nickel alloy), and have an entrainment section of woven stainless steel six times the usual thickness. The design calls for a welded flangeless unit.



Radioactive-waste concentrator

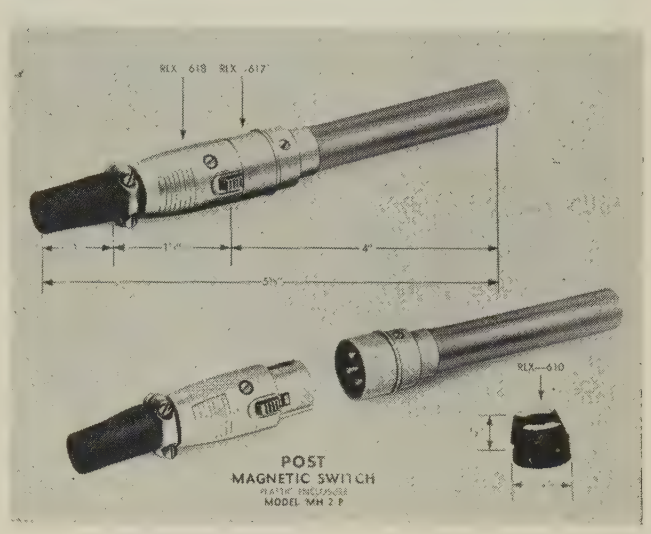
The unit will accept wash-down and purge water from the entire plant (reactor area, laboratory, laundry, and filter backwash operations) and vaporize it so that less than 5 parts in 100 million of dissolved solids are in the discharge. An ion-exchange unit will cut this amount to less than one part in 100 million.

The concentrate of radioactive wastes—up to 30% dissolved solids—will be disposed of according to procedures of the Atomic Energy Commission and New York State.

POST MACHINERY

New Magnetic Switch

The Electronic Products Division of Post Machinery has announced a new and improved magnetic switch which is neatly contained in a plastic (epoxy resin) shell. Called the MH-2-P, this new sensing device for industrial application is easier to mount in areas of limited access, and features a quick disconnect cannon plug. By eliminating elbow type construction the MH-2-P is adaptable to many other applications.



Post magnetic switch

The plastic housing results in less magnetic flux and increased sensitivity. As a consequence, smaller magnets can be used and a minimum magnetic field transient time of only 8 milliseconds is needed to activate the switch. Lifetime is in excess of one billion operations.

Further information can be obtained from the Electronic Products Division, Post Machinery Co., 175 Eliot St., Beverly, Mass.

B & W

Chemical Recovery

The Babcock & Wilcox Co. has developed a variety of power boilers and recovery units which are discussed in a new 26-page bulletin issued by the company's Boiler Div., Barberton, Ohio.

Entitled "Recovery of Heat and Chemicals for the Pulp and Paper Industry," the booklet is divided into five sections: Chemical Recovery, B&W Kraft Recovery, B&W Neutral Sulphite Recovery, B&W Sulphite Recovery, and B&W Power Boilers. Each section presents a summary and detailed data on these topics. Frequent use of line drawings is made throughout the bulletin.

Copies of the booklet, designated as P-2, may be obtained from either Babcock & Wilcox's Boiler Div. headquarters in Barberton or one of the division's 30 sales offices located throughout the United States, Puerto Rico, Cuba, and the Philippine Islands.

Recirculated Gas

Recirculated gas, a major engineering development advanced by The Babcock & Wilcox Co. as the best method for obtaining the proper proportioning of heat with a steam generator, is the subject of a new 16-page bulletin issued by the company's Boiler Div., Barberton, Ohio.

Copies of the booklet, designated as Bulletin G-96, may be obtained from either Babcock & Wilcox's Boiler Div. headquarters in Barberton or one of the division's 30 sales offices located throughout the United States, Puerto Rico, Cuba, and the Philippine Islands.

PANELLIT

Panalarm Catalog

A new 52-page catalog of annunciator systems is now available from the Panalarm Div., of Panellit, Inc., Skokie, Ill., producers of industrial annunciators and process-control information systems.

Extensive information on the function of annunciators and their applications is provided in the catalog. Various types of annunciator equipment are described in full with mechanical and engineering data offered to aid in selecting the proper equipment for any application.

Copies of the catalog are available at no charge. Write for Catalog 100C, Panalarm Div., Panellit, Inc., 7401 N. Hamlin Ave., Skokie, Ill.

Recording Annunciator

Panellit, Inc., 7401 N. Hamlin Ave., Skokie, Ill., has just issued Bulletin 102A illustrating and fully describing its Panalarm Recording Annunciator. Illustrated are both large and small systems, printer and the unique direct-readable alpha-numerical digital tape which requires no time-wasting decoding. Complete technical details include specification data sheet.

Write Panellit, Inc., for Bulletin 102A.

HONEYWELL

Chromatography Recorder

The Honeywell Series 143X chromatography recorder is an ElectroniK, strip chart instrument with features designed especially for vapor phase chromatography recording. These features include continuous standardization, low-inertia pen carriage, high resolution slidewire and provision to add accessories such as a retransmitting slidewire, a manual chart speed changer, limit switches, and recorder feet for portable use. Send for Specification S153-21 from W. A. Lang, Product Editor, Minneapolis-Honeywell Regulator, Co., Industrial Div., Wayne and Windrim Aves., Philadelphia 44, Pa.

Brown Servo Amplifier

The new Honeywell specification sheet S900-4 contains the latest electrical and physical data on the Brown servo amplifiers as well as ordering information. For a copy, send your request to Minneapolis-Honeywell, Wayne and Windrim Aves., Philadelphia 44, Pa.

ElectriK Tel-O-Set System

Honeywell's new ElectriK Tel-O-Set system is an integrated system for the electric process control. It features two-wire d.c. transmission and requires no line power at the field-mounted transmitters and transducers. The complete line of transmitters, transducers, receivers, controllers, and final control elements that make up the system are outlined in specification FS 301-6.

The individual devices are covered in detail by the following new literature:

1. P/I (pressure-to-current) transducer—Specification FS 301-2a.
2. I/P (current-to-pressure) transducer—Specification FS 301-3a.
3. PP/I (process pressure-to-current) transmitter—Specification FS 301-4a.
4. MV/I (millivolt-to-current) transmitter—Specification FS 301-5a.
5. *ElectriK Tel-O-Set* recorders and control stations—Specification FS 301-8.
6. *ElectriK Tel-O-Set* indicators and control stations—Specification FS 301-9.
7. *ElectriK Tel-O-Set* power supply—Specification FS 301-11.

EASTMAN CHEMICAL PRODUCTS

Specialty Chemicals

The complete list of industrial and specialty chemicals offered by Eastman Chemical Products, Inc., subsidiary of Eastman Kodak Co., is now available in a newly published product index.

Copies of this product list may be obtained by requesting Bulletin No. P-102 from the company at Kingsport, Tenn.

UNION CARBIDE

New Data on Surfactants

A new 44-page booklet, describing the properties and uses of Tergitol surfactants, has been published by Union Carbide Chemicals Co., a division of Union Carbide Corp.

The booklet contains extensive data for eight nonionic and four anionic Tergitol surfactants, including selection, solubilities, properties, formulations, applications, performances, specifications and test methods, shipping, bulk storage, and physiological properties. A detailed bibliography and reference section is included.

INDUSTRIAL NUCLEONICS

AccuRay On-Stream Instrumentation No. PI-959, a new 12-page brochure contains information on all process industry measurement and control equipment manufactured by the company. The bulletin includes specifications, applications, and operating characteristics of AccuRay; (1) Continuous Level Measurement Systems, (2) Tank or Bin Level Detector-Controller, (3) Continuous Density Measuring Systems, (4) Container Fill Control Systems, (5) Container Inspection-Rejection System, (6) The Pipewall Thickness Gauge. "AccuRay On-Stream Instrumentation" may be obtained by requesting Bulletin No. PI-959 from Industrial Nucleonics Corp., 650 Ackerman Road, Columbus 14, Ohio.

FISCHER & PORTER

Kimble Glassware Distributors

Fischer & Porter Co., Hatboro, Pa., has been appointed a distributor of the full line of laboratory glassware manufactured by Kimble Glass Co., Toledo, Ohio, a subsidiary of Owens-Illinois. F&P will carry a complete stock, including several new Kimax items just introduced; it will also distribute the new line of glass products with the Kimax Teflon stopcock, which is manufactured under license from F&P. Many special items of laboratory glass apparatus, including custom glassware, will continue to be manufactured by Fischer & Porter.

WESTINGHOUSE

Quartz Infrared Lamps

A new line of quartz infrared lamps (Type T3) for military and industrial applications is now available from the Westinghouse Electric Corp. Five different lamps rating from 500 to 1350 watts and from 5 to 10 in. length are being offered initially, but other sizes will be available in the future.

The compact infrared lamps, made from small-diameter quartz tubes, heat to a temperature in excess of 1000°F. and are so resistant to thermal shock that ice water can be poured over a red-hot lamp without danger of cracking.

For further information, write the Westinghouse Lamp Div., MacArthur Ave., Bloomfield, N. J.

Moduline Gear Drives

Moduline gear drives with an output speed of 420 r.p.m. are now available from the Westinghouse Electric Corp. These units are especially applicable to side entry agitators and permit the use of concentric gear motors at an output speed usually available only in offset shaft construction.

For more information, write Westinghouse Electric Corp., P.O. Box 2088, Pittsburgh 30, Pa.

Electrical Frequency Sensing Governor

A universal electric governor (Model EFG) for use on diesel engines, gasoline engines, steam turbines, and gas turbines is available from Westinghouse. The new unit is designed for

constant speed control over a 10% range in 400-cycle service, and over a 30% range in 50/60 cycle service.

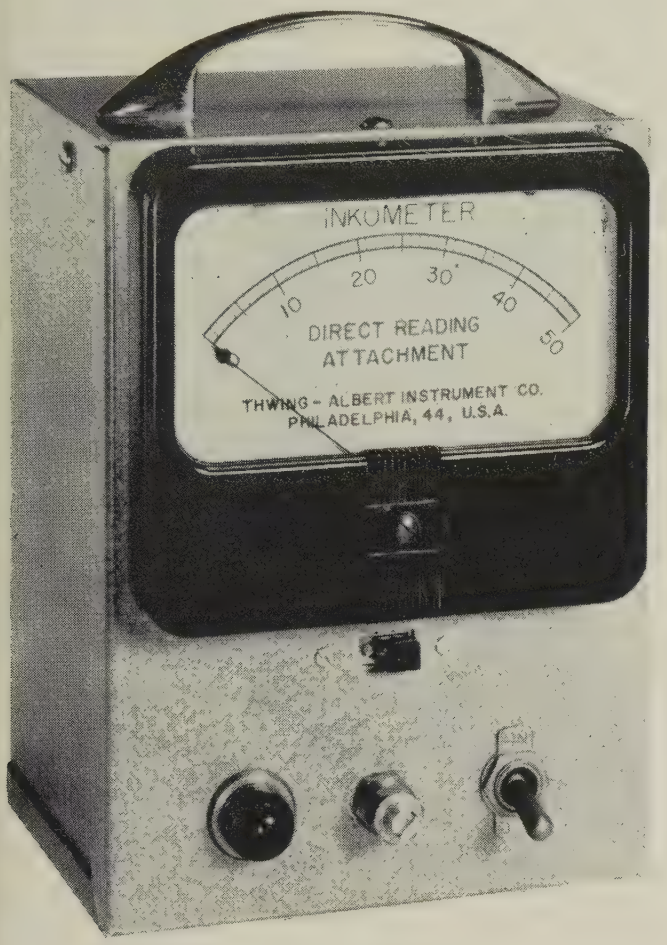
The sensitivity and response characteristics of the governor are measured in milliseconds. The frequency circuit operates within 3 milliseconds of the time of the smallest speed change. Full movement of the throttle from closed position to open position (and vice versa) is accomplished in 0.035 sec.

For further information, write Westinghouse Electric Corp., P.O. Box 2099, Pittsburgh 30, Pa.

THWING-ALBERT

Direct Reading Attachment for Inkometer

Thwing-Albert Instrument Co. announces the development of the new direct reading attachment for use on the Inkometer.



The direct reading attachment, originally designed by the National Printing Ink Research Institute, permits the operator to take Inkometer readings directly on an electric indicator without the necessity of balancing the Inkometer measuring system to get each reading.

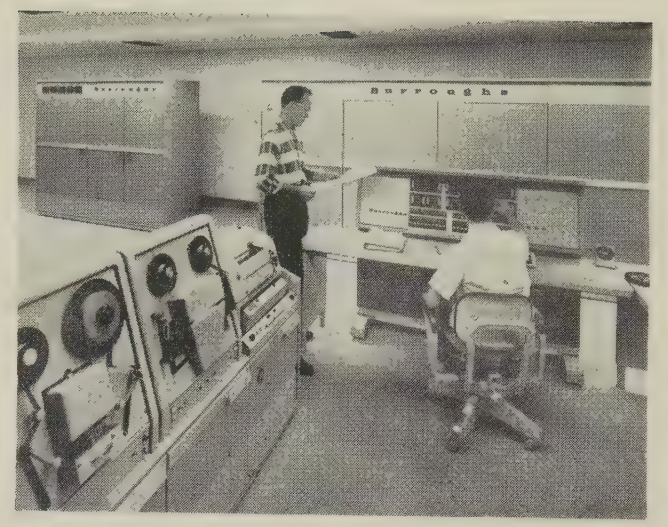
For further information write to Thwing-Albert Instrument Co., Penn St. & Pulaski Ave., Philadelphia 44, Pa.

Dow

New Electronic Computer

The Dow Chemical Co., Midland, Mich., has installed a high-speed, Burroughs 220 electronic computer to hasten the search for new rocket fuels, textile fibers, plastics, and other chemical products.

The 220 computer is capable of performing 7000 to 8000 logical instructions per second and will enable the company to increase its research activity tenfold.



Burroughs' 220 computer

Latex Plant in Connecticut

A new plant to manufacture styrene-butadiene latexes will be built at Allyn's Point, Conn.

Dow also will expand the styrene-butadiene latex capacity of its Texas Division at Freeport. Engineering for both expansions is under way.

The Connecticut plant will become a part of Dow's Allyn's Point Division which manufactures two other major Dow plastics, Styrofoam and Styron. Production of latex there is scheduled for early 1961.

HARCO

Cleaning Solvents

A new series of safety cleaning solvents is claimed to eliminate the wasteful use of high-cost solvents for routine cleaning. The series of 11 standard formulations ranges from low-cost "wash-up" solvents to high safety factor blends for hazardous locations. Literature lists applications, safety factors, flash points, relative drying time, and rather uniquely, a standard price schedule. Available from Harco Chemical Co., Cranford, N. J.

MERIX

Anti-Statics for Silk-Screening and Polyethylenes

Merix Chemical Co., Chicago 49, Ill., has published a new 1960 data sheet on improved Merix Anti-Static No. 79 and Merix Anti-Static No. 79-OL.

Merix Anti-Static No. 79 now enables easy silk-screening on plastics, prevents slippage, improves paint and ink adherence. Merix Anti-Static No. 79-OL shows how polyethylenes can be destaticized permanently.

Free data sheet also lists scientific papers singling out these Merix products for their excellence. Readers should request free data sheets from Dept. 719.

OAKITE

Ultrasonic Cleaning

Alkaline and acidic detergents are frequently better for ultrasonic cleaning than the more viscous solvents. This is one of the six practical tips given in a new service bulletin recently published by Oakite Products, Inc., manufacturers of specialized chemical compounds for industrial cleaning and metal treating.

Based on extensive field work with this fast-spreading cleaning method, the bulletin describes the process by which high-frequency sound waves impart intense scrubbing action to solutions to speed precision cleaning. The method's success, however, depends in large measure on the cleaning

solution, and the bulletin describes compounds which have proved effective, and the types of operation ultrasonic cleaning does best.

Copies of Service Bulletin No. 16A are available from Oakite Products, Inc., 115A Rector St., New York 6, N. Y.

ATLAS

Reinforced Polyester in Filter Plate

A new illustrated 4-page case-history bulletin reports on how Thermaflow 100, a reinforced polyester molding compound, fills a long-standing need for a pressure-filter plate that combines high chemical resistance, smooth texture, light weight, and low cost.

Plates used in pressure filters are normally subjected to hot mineral acids and alkalies, hypochlorites, peroxides, chlorides, and organic solvents and require a material resistant to these conditions.

The Thermaflow case history bulletin may be obtained without cost by writing Chemicals Div., Atlas Powder Co., Wilmington 99, Del.

NALCO

Corrosion Inhibitor

Nalco 339 renders harmless the R_2O_3 group minerals (such as alumina or iron) which otherwise would foul heat transfer surfaces. Thus waterside fouling is eliminated while still maintaining maximum corrosion control.

Nalco 339 rapidly forms a tough, corrosion-resistant film on all metal surfaces. Containing organic and inorganic synergists, it speeds the action of the polyphosphates and produces a more effective protective film than could be formed using straight sodium phosphate.

Further information on this product can be obtained from Nalco Chemical Co., 6216 W. 66th Pl., Chicago 38, Ill.

TOWMOTOR

Fork Lift Trucks

A new roll clamp accessory developed by Towmotor Corp. of Cleveland, Ohio, has the effect of adding extra arms and hands to the fork lift trucks manufactured by Towmotor.

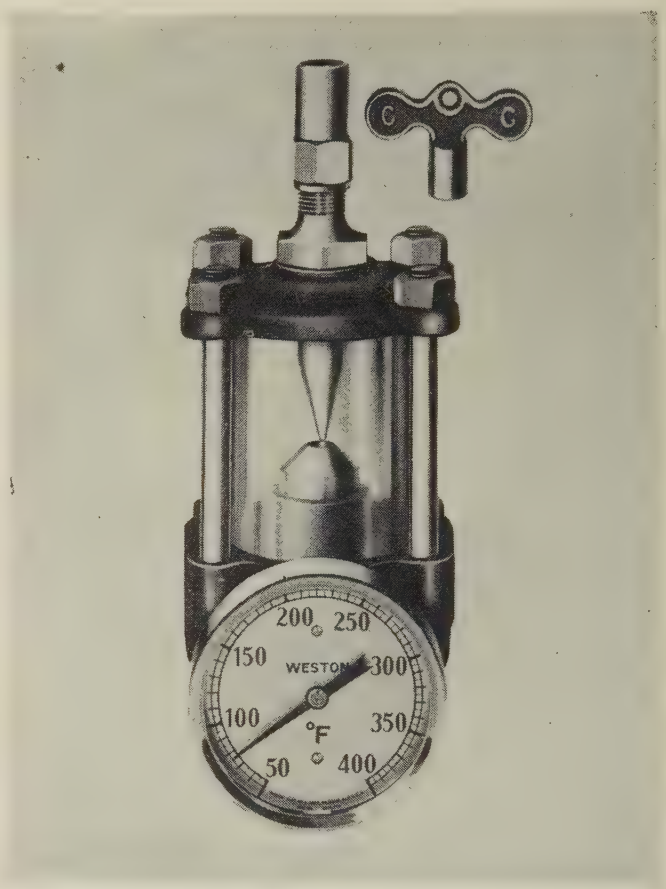
Roll clamp accessory on Towmotor fork lift truck

Installed on a fork lift truck, the roll clamps provide easy handling of paper rolls weighing up to 7000 lb. Rolls can be lifted, lowered, or rotated 360° with the accessory. The upper and lower arms of the clamp as well as many bracing members are fabricated from Jalloy, a high-strength alloy plate manufactured by Jones & Laughlin Steel Corp. Through Jalloy, the weight of the roll clamp is reduced 20% without loss in strength.

STICKLE STEAM SPECIALTIES

Steam Traps Outperformed

A new condensate flow regulator said to outperform steam traps in many applications is offered by Stickle Steam Specialties Co., 2215 Valley Ave., Indianapolis 18, Ind.



Stickle micro adjustable orifice (Series 300)

Known as Stickle micro adjustable orifice (Series 300), the regulator is essentially an adjustable needle valve encased in a sight glass. It is designed to replace steam traps for drainage of heating and processing units operating continually at pressures up to 60 p.s.i.

The orifice is made for pipe sizes from $^1/_2$ to 1 in. and is priced lower than steam traps of equal capacity.

STALEY

Appointments

William (Bill) J. Shaughnessy has joined the A. E. Staley Manufacturing Co., corn and soybean processors of Decatur, Ill., as a paper technical representative in the New York state territory.

OLIN MATHIESON

Expansion

The Chemicals Division of Olin Mathieson Chemical Corp. announced it is planning to expand its electrolytic caustic-chlorine plant at McIntosh, Ala. The announcement was

made by Edward Block, senior vice-president and general manager of the Chemicals Div.

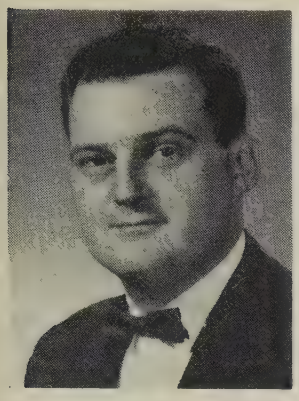
The projected expansion is to meet the needs of the customers in the mid-south, particularly the rayon and the pulp and paper industries and should accommodate these needs for the foreseeable future.

In addition to caustic and chlorine the McIntosh plant manufactures various insecticide products.

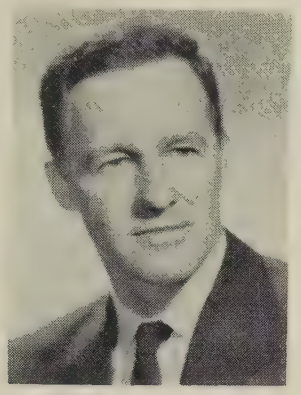
Cameron

Appointments

Cameron Machine Co., Dover, N. J., manufacturers of slitting and roll winding machinery, have announced two changes in sales territorial coverage.



Richard Sherman, Cameron sales Representative



W. R. Ebersold, Cameron sales Representative

Richard Sherman, who has been Cameron's representative in the metropolitan New York area, will now also cover New Jersey and Connecticut. Mr. Sherman has been associated with Cameron for several years and was formerly a senior service engineer.

W. R. Ebersold has been appointed representative for the middle Atlantic States, including Pennsylvania, Maryland, Delaware, West Virginia, and Virginia. Mr. Ebersold was formerly associated with Gaylord Container Corp., Division of Crown Zellerbach Corp.

Pfaudler Permutit

Appointments

The Permutit Division of Pfaudler Permutit Inc. has announced the addition of three more regional sales engineers. According to Morris Wolfe, manager of the Chemical Sales Department, Timothy J. Hennigan is now responsible for sales in all of New England, David C. Loveland is covering central New Jersey, and Paul E. Browne is in charge of the greater Philadelphia area, including southern New Jersey.

Jefferson

Appointments

Three recent appointments to the research staff of Jefferson Chemical Co.'s Austin Laboratories were announced today by R. F. McCleary, general manager of the company's Research & Development Department. The four scientists are: Richard L. Rowton, A. A. Szemborski, Walter H. Brader, Jr., and Elaine Peters.

Allied Chemical

Appointments

Appointment of John W. Priesing as manager of the newly established West Coast Sales Branch of Solvay Process Div., Allied Chemical Corp., was announced recently by Arthur Phillips, Solvay's vice-president.

General Aniline

Appointments

Charles F. Jelinek has been appointed manager, new fields research at the Central Research Laboratories, Easton, Pa., of General Aniline & Film Corp.

Dr. Jelinek replaces Joseph M. Wilkinson, Jr., who was recently promoted to Director of Development of the company's newly created corporate Development Department.

Morden

Expansion

A new addition that enlarged office space by 30% has been completed at the Morden Machines Co., 3420 S. W. Macadam Ave., Portland, Ore., according to president R. Burke Morden.

Enlarged H.Q. for Morden Machines

The added offices will be used primarily for expanding the administrative, engineering, and sales departments. Research and laboratory facilities were enlarged also to further the company's testing and development program.

The company manufactures stock preparation machinery for the pulp and paper industry.

J. O. Ross

High Velocity Driers

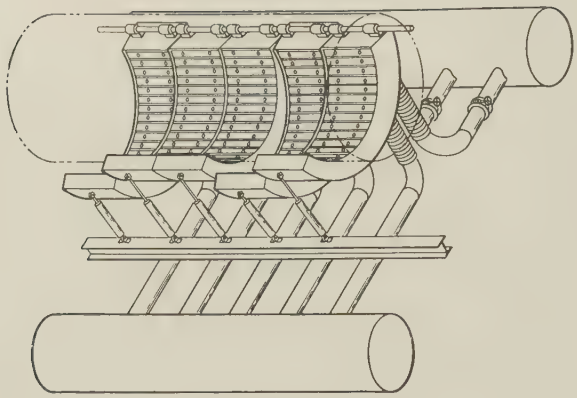
Over 30 years of experience in the field of high velocity drying has culminated in the development of three basic high velocity drier types by J. O. Ross Engineering, Div. Midland-Ross Corp. The new units are specially designed for the pulp and paper field although variations in design make them applicable in other web treating industries.

In the paper, textile, and other web treating industries, high velocity driers increase productivity by drying faster and more uniformly than conventional driers. Thus, product quality is improved and substantial economies in operating costs are realized.

The three Ross high velocity driers are designed, constructed and installed according to needs of the individual application.

The Ross "SP" Drier

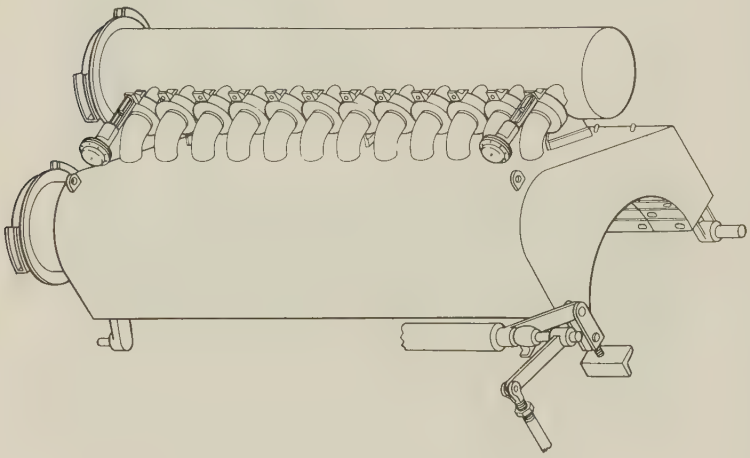
The Ross SP high velocity drier has individual curved heads, installed side by side across the width of the sheet. Each may be raised or lowered independently. Supply air can also be controlled for volume and temperature.



"SP" high velocity drier

The Ross "DL" Drier

This high velocity drier similar to the SP except that the sections are not individually movable, is a solid head running the width of the sheet. The entire head can be adjusted for volume and temperature controls. It can be raised to clear broke easily and is versatile enough to level the sheet in case of nonuniform moisture content.



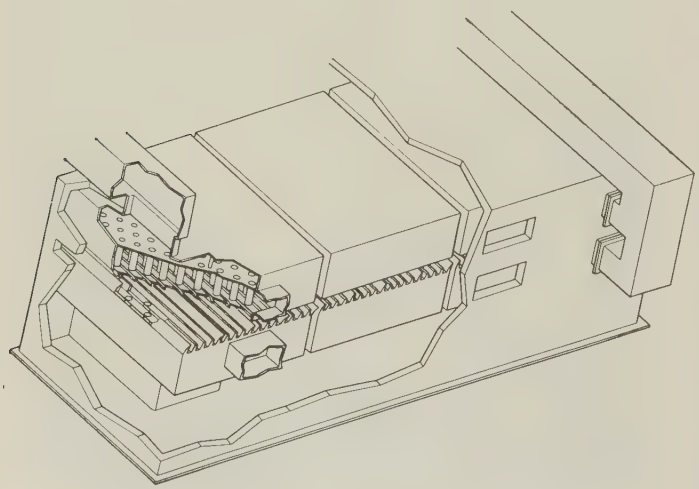
"DL" high velocity drier

The Ross "RD" Drier

The Ross RD high velocity drier is a revolutionary advancement in straight pass drying. It utilizes high velocity air and controlled temperatures to greatly increase drying capacity and reduce operating costs. The shorter length of the unit results in saving valuable floor space and reduced maintenance.

The Ross straight pass RD drier is equipped with nozzles designed for moving the web on air as well as drying it. This saves on conventional methods of conveying the material, while insuring a mar-free finish.

For complete information on these three driers J. O. Ross Engineering, Div. Midland-Ross Corp., 730 Third Ave., New York 17, N. Y., has published a 4-page bulletin dealing with high velocity drying.



"RD" high velocity drier

TAYLOR-WHARTON

Crawler Parts Brochure

A 4-page brochure illustrating the Tisco line of bulldozer sprocket rims, tractor pads, end bits, and blades, is now offered by the Taylor-Wharton Co., Division of Harsco Corp. Operating advantages of Tisco renewable, work-hardening manganese steel parts are outlined, and stock part specifications for all first-line crawlers are tabulated. The two-color brochure also describes procedures for rapid installation of Tisco sprocket rims. For your copy, write Taylor-Wharton Co., High Bridge, N. J.

POTTSTOWN METAL PRODUCTS

Industries Catalog

Pottstown Metal Products, Division of Cochrane Corp. has published a catalog showing typical fabrications for the chemical, petroleum, petrochemical, water conditioning, paper, paint, power generation, pharmaceutical, food, and nuclear industries.

Welded vessels of interest to engineers and operating management include shells for some of the world's largest deaerating feedwater heaters, demineralizers of Type 304 stainless steel for a marine nuclear plant, and complex stainless-clad epoxy resin reactors. Nearly 50 pressure vessels are described and illustrated, covering nearly every type of industry.

In addition, one section of the brochure describes the new PMP vacuum fumigation system. The company markets complete installations, which have found wide use in the treatment of such commodities as grain, tobacco, dried fruit, seeds, nuts, cotton, and wool.

POWERS REGULATOR

New Reverse Relay

Pneumatically controlled industrial processes can be given "fail-safe" protection in case of air line failure with a compact new reverse relay.

Powers regulator, Reverse relay Type 783

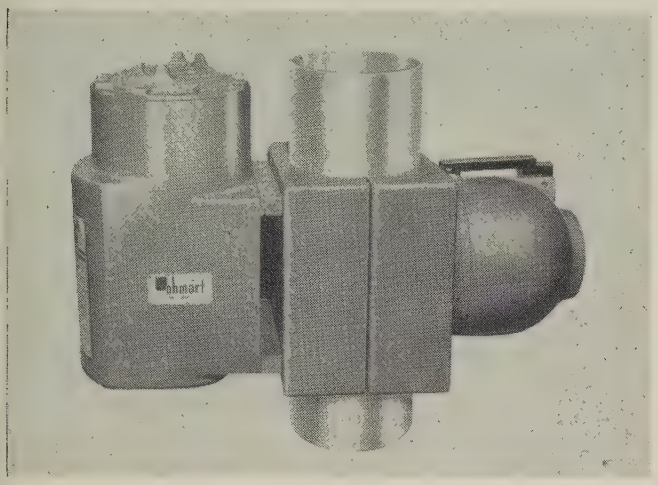
Made by the Powers Regulator Co., Skokie, Ill., the Type 783 reverse relay, 60% smaller than its predecessor, is an auxiliary device which gradually reverses the action of pneumatically operated valves, motors, and dampers.

Additional information is available in Form P-82 from the Powers Regulator Co., 3434 Oakton St., Skokie, Ill., or from the Powers Regulator Co. of Canada, Ltd., 15 Torbarrie Rd., Downsview P.O., Toronto, Ont.

Ohmart Corp.

Automatic Density Gage

Two new density gages are available for automatically measuring the specific gravity or per cent solids of liquids flowing through pipes up to 8 in. diam. Model PGV and PG both utilize a point source of radioactive material and an Ohmart measuring cell; the cell detects radiation energy in



Automatic density gage

proportion to the density of the material flowing past the gage and changes it into an electrical signal which is amplified and fed to a recorder or controller for actuating pumps or valves.

Additional information is available from the manufacturer: Ohmart Corp., 2236 Bogen St., Cincinnati 22, Ohio.

Conax

Thermocouples

A new line of Conax Con-O-Clad mineral-insulated thermocouples provides flexibility that permits bending into an unlimited number of configurations; high temperature range up to 3000°F.; small size probes from 0.040 to 0.375 in.; response rate which is practically instantaneous; long life with thermocouple wires encased by inert minerals in airtight chamber; shock- and vibrationproof; and corrosion resistance from a wide choice of sheath metals.

For complete information on Conax Con-O-Clad, write to the Conax Corp., 2300 Walden Ave., Buffalo 25, N. Y., for 20-page fully illustrated, functionally colored Catalog 300.

Syntron

Mechanical Conveyor Screens

Syntron Co. announces the availability of a new catalog section on mechanical conveyor screens, designed for the scalping and coarse and medium sizing of a wide range of bulk materials.

The illustrated section contains complete descriptions, specifications, and data for three standard mechanical conveyor screen models.

Free copy of catalog section available immediately—upon request from Syntron Co., 1381 Lexington Ave., Homer City, Pa.

Stokes

Size-Reduction Equipment

Two proved designs of Stokes size-reduction equipment—the new "Tornado" mill and the well-established Model 43-B oscillating granulator—are described in a new 4-page bulletin, No. 350, just issued by F. J. Stokes Corp., Philadelphia.

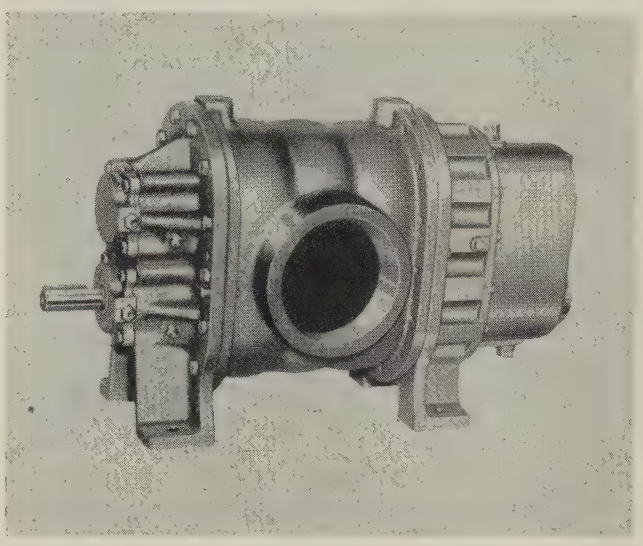
The model 43-B oscillating granulator is known throughout industry and particularly in the processing of extremely friable and other "problem" materials, on which it gives superior screen analyses.

Copies of Bulletin No. 350 are available free on request from F. J. Stokes Corp., 5500 Tabor Rd., Philadelphia 20, Pa.

Roots-Connersville

Small Vacuum Blowers

Ten sizes of small-volume vacuum blowers comprise the new line being offered by Roots-Connersville, a division of Dresser Industries, Inc., Connersville, Ind., Designed for capacities from 30 to 1000 cu. ft. per min. and vacuum to 20 in. Hg in single-stage application, these units may be compounded for vacuum service over 20 in. Hg. These new Roots units provide the same efficient, trouble-free operation experienced with the larger rotary positive Roots vacuum blowers.



Roots-Connersville vacuum blower

For details of construction, selection, and application of these small new vacuum blowers, write Roots-Connersville, Connersville, Ind. For helpful information on the larger sizes of Roots vacuum blowers, write for bulletin VP-158.

Wallace & Tiernan

Purge Meter Line

Wallace & Tiernan Inc., Belleville, N. J., has put into production a new line of glass tube purge meters. These low capacity flowmeters will withstand the toughest industrial uses. Their design includes features which make them convenient and reliable in purge, liquid level control, or other applications.

The stainless steel purge meters are available in various sizes. Metering tubes are either 3 in. scale for easy readings, or $^1/_2$ in. scale for space saving. Except for the metering tube and frame, all purge meter parts are interchangeable, regardless of scale length. The metering tubes and floats cover a flow range of 0.01 to 30.0 gal. of water per hour, or 0.12 to 125.0 standard cu. ft. of air per hour.

Technical publication TP-1-RM, giving further information, is available from Wallace & Tiernan, Inc., Belleville 9, N. J.

Left: Wallace & Tiernan 3 in. purge meter with control valve. Right: 1-½ in. purge meter without control valve

INFILCO

New Instrument System

New "C.-A.-P. System" instruments for automatic operation and control of filter plants are now available for operation on 3 to 15 p.s.i. output pressures.

These instruments are described in Bulletin 1100C and they include integrated components for opening, closing, and modulating valves, regulating chemical feed rates, and indicating and recording flow rates, levels, and pressures.

Copies of above bulletins available upon request to Infilco Inc., Tucson, Ariz.

DORR-OLIVER

Disk-Type Saveall

Dorr-Oliver Inc., announces the availability of a new, 4-page bulletin, "The American (disk-type) Saveall." This bulletin, No. 3306, details the principles of operation, design characteristics, and advantages of this filter, widely used in the pulp and paper industry, for recovery of suspended solids from paper machine white water. Also included are photographs and flowsheets of typical plant installations.

Copies of Bulletin 3306 are available at no obligation from Dorr-Oliver Inc., Stamford, Conn.

LEEDS AND NORTHRUP

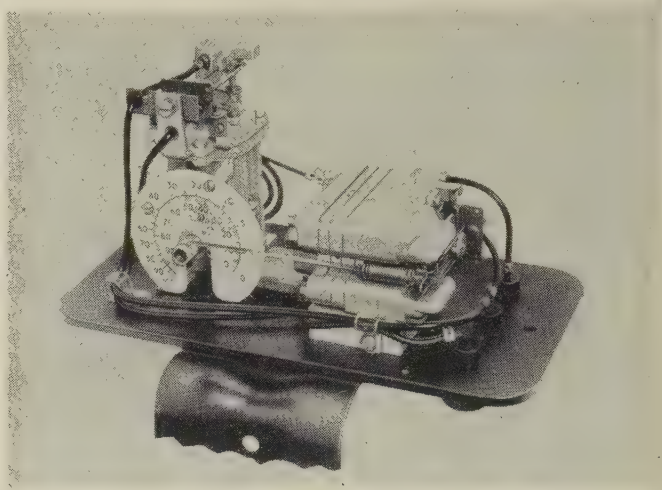
Data Processing Equipment

A new 48-page publication describes Leeds & Northrup Co. data processing equipment in use, including digital data processing and analog and digital computing systems. Well illustrated, it explains types of inputs, input switching, output devices, and modes of operation for applications in electric power, petrochemical, aeronautics, agriculture, and other fields. For a free copy, write L&N, 4934 Stenton Ave., Philadelphia 44, and ask for Preliminary Technical Publication N-07(1).

TAYLOR INSTRUMENT

Function Generator

Taylor's new function generator converts a pneumatic input signal into a characterized output. Its principal use is in linearizing the signal from a differential pressure type flow transmitter. This assures quicker, more accurate readout on linear scales and charts. This versatile unit offers the further advantage of optional interchangeable cams which perform an unlimited variety of functions other than the linearization of flow measurement.



The Taylor function generator

It is of particular interest in the measurement and control of feedwater or steam flow in power production (as a public utility, or in connection with product processing). It is also of interest in the chemical, petroleum, paper pulp, and food processing fields for such applications as: (1) the ratioing of flows involving viscous liquids, slurries, colloidal suspensions, or liquids that "gel" when not in motion; (2) cascade control systems involving flow and a linear variable measurement such as temperature, pressure, or liquid level; (3) totalizing several measured variables such as temperature and flow.

Request Bulletin 98369 from Taylor Instrument Cos., Rochester 1, N. Y.

G.E.

Recorder

Complete specifications for proper selection of general Electric recorders—Bulletin GEA-6933 (12 pages, two color)—provides buying information on complete line of recording instruments, including dimensions and chart speeds, operating specifications, applications, features, and accessories. Recorders are grouped by accuracy class (¼, 1, 2, and 3%) for convenient selection. Photographs of all models discussed are included. Bulletin also describes specialized recording instruments available, such as spectrophotometers, recording vibrometers, automatic oscillographs, self-balancing potentiometers, and speed recording systems.

General Electric Co., Schenectady 5, N. Y.

SPROUT, WALDRON

Pneumatics Cuts Carloading in Half

Carloading time of primary clay at Harris Clay Co., Spruce Pine, N. C., has been cut in half through the use of pneumatic handling. The fine clay is now being handled at rates to 18 tons per hr. The installation of the Sprout, Waldron negative pressure Pneu-Vac® pneumatic system

The Pneu-Vac cyclone and rotary vane feeder

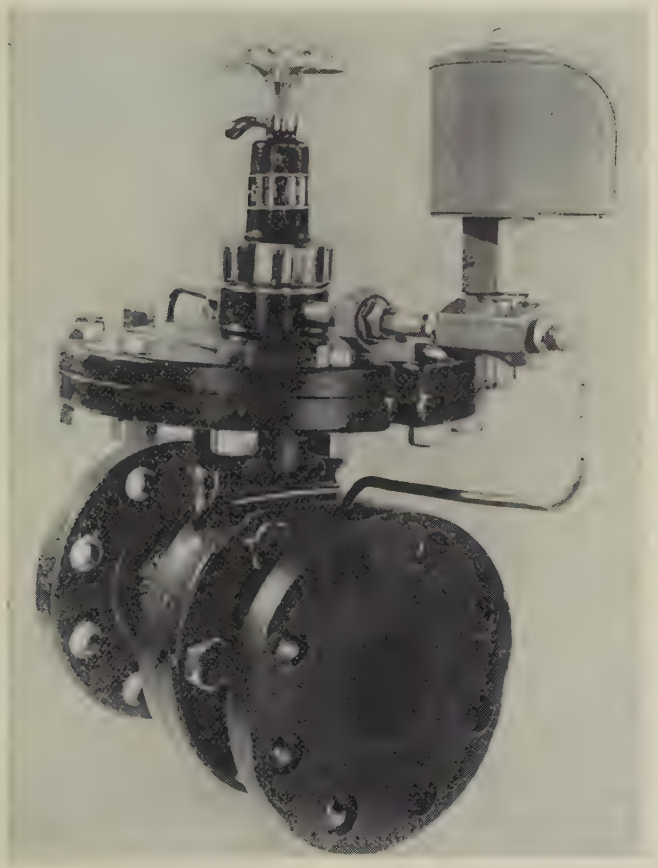
has cut the unloading operation of 6 to 8 hr. down to 3 hr.

Further details from Sprout, Waldron & Co. Inc., 130 Logan St., Muncy, Pa.

OPW-Jordan

Solenoid Actuated Regulators

Solenoid actuated regulators for on-off control are now available from OPW-Jordan. Widely used in industry wherever remote shut-off, remote start-up, automatic safety shut-off, and combination pressure and temperature control with



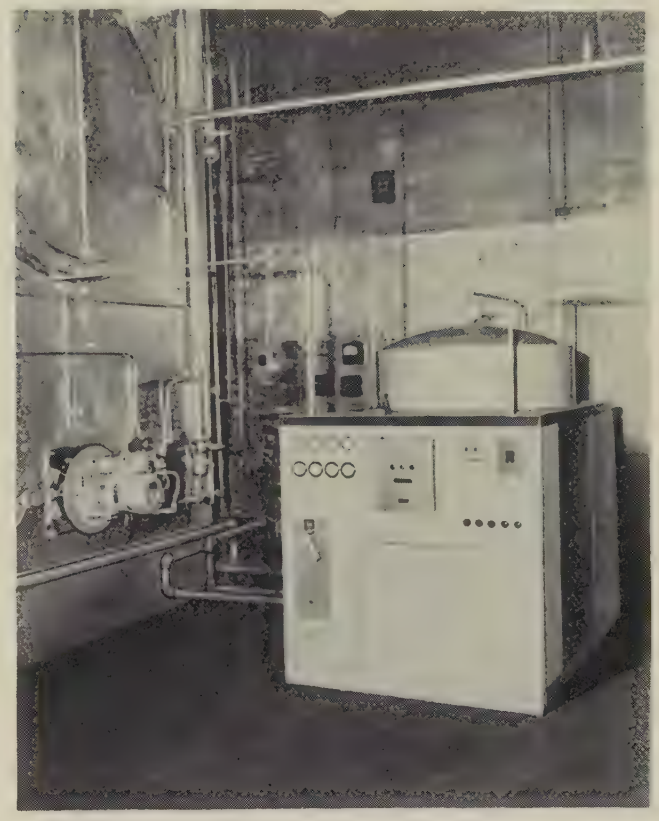
The Solenoid Actuated Regulator

an electric signal are needed. The open solenoid allows steam to enter the pilot chamber and operate the main valve as a normal pressure regulator. When closed, the steam supply to the pilot is shut off and the main valve closes automatically. Complete description and illustrations available in bulletins SRBc, 62–59, and JNP-1. Write OPW-Jordan, 6013 Wiehe Rd., Cincinnati 13, Ohio.

Sparkler-Filtrion

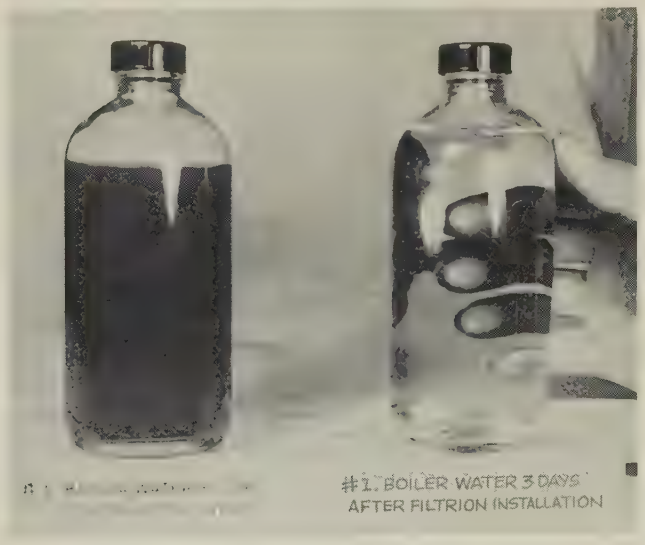
Side-Stream Boiler Waier Control

A low-cost side-stream boiler water control system that automatically keeps boiler water crystal clear by eliminating



Filtrion Side-Stream Automatic Boiler Water Control System

sludge and suspended solids has been introduced by the Sparkler-Filtrion Corp., North Chicago, Ill.



Boiler water before and after Filtrion installation

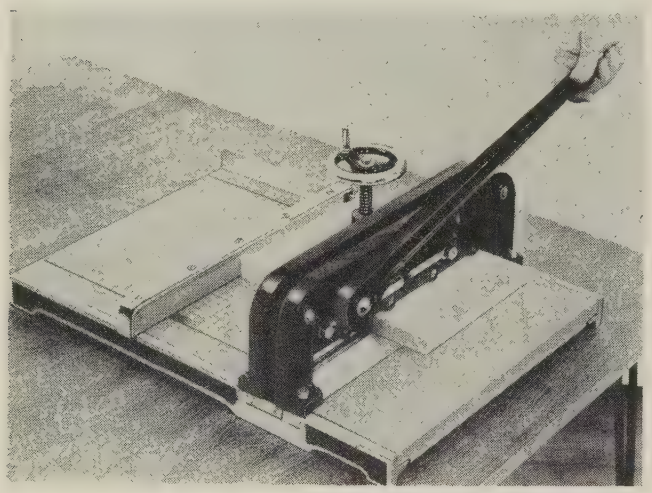
This new Filtrion side-stream automatic boiler water control developed for heating, process and power boilers, continuously recirculates boiler water through an exclusively effective side-stream filter that reduces suspended solids to a value close to zero. It combines and integrates this side-stream filtration with chemical pretreatment, internal treatment, continuous minimum blowdown and feedwater preheating and degassing all in one completely automated unit. The system is guaranteed by the manufacturer to operate boilers at conditions better than industry standards set up for steam quality guarantees.

Complete information on the new Filtrion side-stream boiler water control system, prices, and side-by-side boiler operation comparison data may be obtained by writing to the Sparkler-Filtrion Corp., North Chicago, Ill.

Douglas Homs

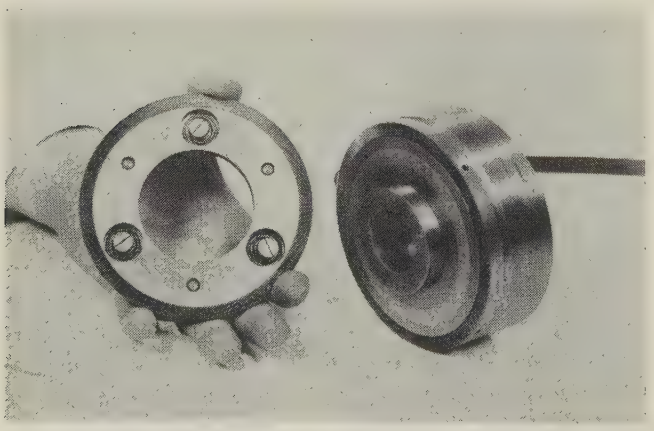
Paper Cutter

The Douglas Homs Co., 326 Jackson St., San Francisco 11, Calif., offers its new Model 14 table-top guillotine paper cutter for use in business, schools, print shops, letter shops, and all other activities where paper is used. The unit incorporates at low cost features of the more expensive guillotine cutters. Included are: a pull-out safety device, heavy-duty



Douglas homs paper cutter

paper press, full-length side guide, full-width adjustable back guide, ruled table, and two ruled metal inserts for quickly inserting paper to desired length for cutting. The model has a capacity of approximately 300 sheets with widths up to $14^1/_2$ in.



Stationary Field Face-Tooth clutch by I-T-E Circuit Breaker Co.

I-T-E

New Face-Tooth Clutches

A new series of face-tooth type clutches has been added to the line of stationary-field electromagnetic clutches produced by I-T-E Circuit Breaker Co., Philadelphia.

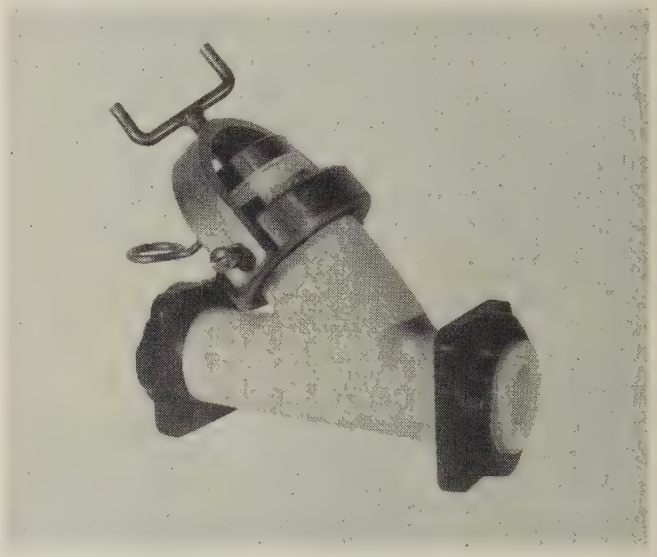
Available in five ratings from 30 through 725 lb.-ft. of torque, the new units provide the highest torque in the smallest space of any commercially available stationary field clutches for such applications as machine tool feed, tracer, and positioning drives.

Detailed application information may be obtained by inquiry to I-T-E Circuit Breaker Co., 1900 Hamilton St., Philadelphia 30, Pa.

Lapp Insulator

All Porcelain Strainer

An all porcelain strainer especially designed for removing both coarse and fine solids before they enter chemical pumps, valves, or other similar process equipment, is now available from the Process Equipment Division of Lapp Insulator Co., Inc., LeRoy, New York.



All porcelain strainer

The body of the strainer is made of solid chemical porcelain; the unit's end seal is Teflon. Connecting flanges of the strainer are malleable iron and are drilled for 150 ASME bolting. All other trim is stainless steel.

Three fused porcelain sand strainer elements are available with average pore diameters of 250, 150, and 110 microns.

For further information concerning the all porcelain strainer, write to the Process Equipment Div., Lapp Insulator Co., 106 Hall St., LeRoy, N. Y.

Joy Mfg.

6-Button Pendent Switch

The Joy Pendent "Safe" Switch is now available in a 6-station as well as a 4-station model, according to new illustrated literature released by the Electrical Products Division of the Joy Manufacturing Co.

The reader can readily see the switch wells, water seals, and micro-type positive switches in position. The entire unit is enclosed in HyCar, an improved synthetic rubber compound, and is completely watertight and corrosionproof.

For a copy of this literature, write to the Electrical Products Div., Joy Manufacturing Co., 1201 Macklind Ave., St. Louis 10, Mo.

TAPPI DIVISIONS AND COMMITTEES

Reports of Activities

Converting and Consuming Division

The meeting was held at the Edgewater Beach Hotel, Chicago, Ill., Sept. 20 and 21, 1959. Present were:

R. C. Sturken, *chairman*, F. W. Egan & Co.
J. C. Pullman, *vice-chairman*, American Cyanamid Co.
H. A. Spencer, Knowlton Bros.
W. N. Stickel, Texon, Inc.
H. O. Teeple, TAPPI
A. J. Winchester, TAPPI
V. T. Stannett, *secretary*, College of Forestry

The fall meeting program was discussed. It was agreed that the 1961 meeting would be held at the French Lick Hotel, French Lick Springs, Ind., on Oct. 9–11, 1961, and that the 1962 meeting should be held in October in Boston, Mass.

A. J. Winchester, TAPPI; H. A. Spencer, Knowlton Bros.; J. C. Pullman, American Cyanamid Co.; R. C. Sturken, F. W. Egan & Co.; V. T. Stannett, State University of New York College of Forestry; and W. N. Stickel, Texon, Inc.

The committee for the 1960 meeting to be held in Syracuse, N. Y., October 17–19 was appointed as follows: V. T. Stannett, State University College of Forestry, Syracuse 10, N. Y., general chairman; Richard W. Loheed, Chas. T. Main, Inc., technical program chairman; and Clifford G. Morse, Sealright-Oswego Falls Corp., Fulton, N. Y., local arrangements chairman.

The broad program for the meeting was discussed and the following sessions agreed upon:

1. Wet Strength Committee, *chairman*, K. W. Britt
2. Laminates Committee, *chairman*, H. A. Spencer
3. Plastics Committee, *chairman*, W. N. Stickel
4. General Session, *chairman*, W. A. Howells
5. Panel on Synthetic Fibers, *chairman*, T.B.A.

There will be a visit to the laboratories of the College of Forestry and one possible other plant visit. The banquet will be on the Monday evening and the visit on Tuesday afternoon.

It was agreed that titles and authors of papers should be known by May 5, abstracts by August 6, and the full text of papers by September 6.

A number of suggestions were considered for expanding the activities of the division. These included the setting-up of a consumers committee, and a committee to consider problems connected with paper shipping sacks. A further possible committee would be concerned with nonwoven fabric type materials formed on the paper machine. These and other suggestions will be considered and discussed at the February national meeting in New York City.

V. T. Stannett, Secretary

Chemical Engineering

The Chemical Engineering Committee of TAPPI had a luncheon meeting at the Hotel Commodore, New York City, Feb. 24, 1959, during the annual TAPPI meeting. A. W. Plummer presided. Members present were:

A. W. Plummer, *chairman*
R. F. Clemens, *secretary*
E. C. Bowen
C. W. Carroll
A. J. Chase
W. G. Dedert
S. A. Dunn
R. W. Hisey
L. C. Jenness
John Lewis
C. S. Matson
J. L. McCarthy
E. F. Thode
R. P. Whitney
L. W. Zabel

Guests Present

E. H. Dallgren
V. P. Owens

U. P. Owens spoke briefly about the Pittsburgh meeting.

Minutes of the Portland meeting were read and accepted. E. F. Thode reported on the Operations Research Subcommittee and mentioned the technical session papers to be presented at the Pittsburgh meeting, including a paper by Joel Hougen, of Monsanto Chemical, on the "Understanding of Chemical Processes Necessary for Systems Engineering," and one on the Scott Paper Co. analog computer.

Chairman Plummer commented further on the excellent program planned.

L. C. Jenness reported on the Subcommittee on Chemical Engineering problems. This subcommittee has been fully appointed and a separate meeting will be held in the near future outside of TAPPI.

Mr. Jenness felt that problems would be classified as to process, i.e., sulphate, kraft, semichemical, etc., following respective flowsheets.

An appropriation of $2000 has been requested from TAPPI for editing, etc., of these problems. It was reported by E. C. Bowen that this appropriation had been approved.

Further discussion on the organization of these problems brought out a suggestion by Mr. McCarthy that the problems be organized on the basis of unit operations rather than flowsheet. Also, Mr. Thode mentioned that it should be appreciated that these problems should be intended for staff members' use in educational courses.

Professor Chase reported on the Subcommittee on Data Sheets and outlined the program of reviewing and revising data sheets and assignments for the Pulp and Paper Hand-

book. The reviewing of existing sheets is a sizable job and it has been decided that the old sheets should be reviewed and brought up to date before tackling new sheets. Mr. McCarthy expressed an interest in exactly what the Pulp and Paper Handbook was to consist of and who was doing it. Mr. Plummer answered that the Engineering Data Sheet Committee is handling it and H. G. Ingraham is chairman.

Discussion followed on the necessity of such a handbook, pointing out the fact that these data could either be assembled in data sheet form or in handbook. Mr. Dedert felt that data sheets were more flexible.

Finally, the following resolution was discussed and passed: "The Chemical Engineering Committee recommends that the preparation of the Pulp and Paper Handbook be considered with the objective of restricting its contents to data not readily available in existing reference books."

Mr. Plummer reported on the Education Subcommittee. The purpose of this committee is (1) to survey the number of chemical engineers in the pulp and paper industry and this has been done and reported, and (2) expand program to encourage chemical engineers to enter the industry. A program is being considered to contact industry in connection with item (2). Progress Report 626 has been submitted to TAPPI. Also the work of this project is acknowledged and supported by APPA. They have suggested similar surveys covering other types of engineers.

Project 121 on humidity measurements is still under way but without TAPPI support. Now being sponsored by a Wisconsin Alumni group.

Mr. Plummer explained that our subcommittee organization should be distributed to all members in the near future. Also, our policy now is that all members should be on a subcommittee where active participation in our programs can be carried out. Reports of subcommittee chairmen are requested to be submitted on March 1, June 1, and October 1.

The meeting was adjourned at 2:00 p.m.

R. F. Clemens, *Secretary*

Chemical Engineering Committee

A. W. Plummer, *chairman*, Hudson Pulp & Paper Co., South Windham, Me.
E. C. Bowen, The Bowen Corp., Cambridge, Mass.
C. W. Carroll, Scott Paper Co., Chester, Pa.
R. F. Clemens, *Secretary*, Dorr-Oliver Inc., Stamford, Conn.
A. J. Chase, University of Maine, Orono, Me.
Stanley A. Dunn, Rhodia Inc., New Brunswick, N. J.
J. F. Gorham, University of Maine, Orono, Me.
R. W. Hisey, S. D. Warren Co., Cumberland Mills, Me.
J. H. Hull, Crown Zellerbach Corp., Seattle, Wash.
L. C. Jenness, University of Maine, Orono, Me.
John Lewis, Lowell Technological Institute, Lowell, Mass.
C. S. Matson, Gilbert Paper Co., Menasha, Wis.
J. L. McCarthy, University of Washington, Seattle, Wash.
W. K. Neill, University of Wisconsin, Madison, Wis.
S. M. Neuville, Kimberly Clark Corp., Neenah, Wis.
G. Rowlandson, Kimberly Clark Corp., Neenah, Wis.
Edward F. Thode, Institute of Paper Chemistry, Appleton, Wis.
J. E. Vivian, Mass. Institute of Technology, Cambridge, Mass.
H. L. Warner, P. H. Glatfelter Co., Spring Grove, Pa.
Roy P. Whitney, Institute of Paper Chemistry, Appleton, Wis.
L. W. Zabel, Kimberly-Clark Corp., Neenah, Wis.

Corrosion Committee

During the 14th Engineering Conference of TAPPI (Oct. 13, 1959), the Corrosion Committee had a luncheon meeting at 12:30 p.m. The following members and guests were in attendance:

W. C. Barnwell, Crown Zellerbach Corp., Gaylord Container Div., Bogalusa, La.
Z. Blanchard, Portland Co., Portland, Me.
W. K. Boyd, Battelle Memorial Institute, Columbus, Ohio.
A. O. Caldwell, Service & Erection Co., Pittsburgh, Pa.
H. M. Canavan, Mutual Boiler & Machinery, Insurance Co., Waltham, Mass.
M. Cyr, Fraser Co.'s Ltd., Newcastle, N. B., Canada.
R. A. Davis, Chicago Bridge & Iron Co., Birmingham, Ala.

Corrosion Committee

*L. Dela Grange, West Virginia Pulp & Paper Co., Sandusky, Ohio.
H. P. Evans, C. F. Braun & Co., Alhambra, Cal.
H. W. Fritts, Aluminum Co. of America, New Kensington, Pa.
W. C. Gerstacker, National Annealing Box Co., Washington, Pa.
*W. Hammond, West Virginia Pulp & Paper Co., Covington, Va.
H. B. Harris, Jr., Union Bag-Camp Corp., Savannah, Ga.
W. Henricks, Mead Corp., Chillicothe, Ohio.
*R. Herold, Taylor-Wharton Co., High Bridge, N. J.
E. W. Hopper, 905 Union Trust Bldg., Pittsburgh, Pa.
R. L. Horst, Jr., Aluminum Co. of America, New Kensington, Pa.
R. Kesler, Institute of Paper Chemistry, Appleton, Wis.
*R. B. Laine, Southern Corp., Charleston, S. C.
A. R. Meyer, Graver Tank & Mfg. Co., East Chicago, Ind.
J. B. Morrison, Crucible Steel Co., Waltham, Mass.
W. A. Mueller, Pulp & Paper Research, Institute of Canada, Montreal, Canada.
W. B. Parker, Hartford Steam Boiler Insp. & Insurance Co., Hartford, Conn.
*R. S. Rote, Lukens Steel Co., Coatesville, Pa.
*E. Scholz, West Virginia Pulp & Paper Co., Covington, Va.
*R. Smith, Pfaudler Co., Rochester, N. Y.
R. C. Stamm, West Virginia Pulp & Paper Co., New York, N. Y.
H. O. Teeple, TAPPI, New York, N. Y.
B. Thomas, Stebbins Eng. & Mfg. Co., Watertown, N. Y.
R. B. Watson, Corrosion Service Ltd., Toronto, Canada.
F. D. Whitehead, Jr., West Virginia Pulp & Paper Co., Covington, Va.
*W. L. Williams, C. F. Braun & Co., Houston, Tex.

* Guests.

After lunch, Committee Chairman Hopper, opened the meeting by introducing the members and guests. Both the minutes of the Feb. 25, 1959, meeting and the interium meeting on overlay of carbon steel digesters, which was held on June 2, 1959, in Pittsburgh, were reviewed. No corrections or additions were offered.

The report on the present status of the committee showed 39 members—12 representing pulp and paper companies and the balance from allied industries, research activities, or consultants. During the meeting Mr. Henricks of Mead Corp. turned in his application for committee membership, so we now have a total of 40 members—13 from the pulp and paper industry. A complete up-to-date list of members follows this report.

Mr. Hopper pointed out that the committee did not have a vice-chairman at the present time, but that steps were being taken to fill this position.

It was announced that the present secretary of the committee was moving from the TAPPI Engineering to the Converting Division and would be resigning as secretary of the Corrosion Committee. Immediate steps will be required to fill this post.

The Corrosion Committee presently has five subcommittees which have not been active for several years. It will be necessary to have subcommittee chairmen and secretaries in order to get active programs going. Immediate steps will be taken to fill these posts.

Because of the great interest in alkaline digester corrosion and overlay of carbon steel digesters, it was proposed that another subcommittee on this subject be formed. Steps also will be taken to obtain subcommittee officers for this new subcommittee.

Mr. Hopper reminded the committee members that the Corrosion Committee was set up to handle and investigate all kinds of corrosion problems in the pulp and paper industry. He is particularly anxious to expand the activities beyond alkaline digester corrosion.

"Obligations of Committee Members"—Mr. Teeple of TAPPI headquarters reviewed the obligations of committee members. He pointed out that committee members are expected to attend scheduled committee meetings regularly, to reply promptly to all committee correspondence, and to perform committee assignments to the best of their ability. The overall performance of any committee is only as good as the performance of its individual members.

Mr. Hopper then pointed out the necessity of reorganization of the subcommittees on alkaline pulping, acid pulping, neutral sulphite pulping, pulp purification, alkaline digester corrosion and overlay, and the subcommittee activities covering data sheets. The first step in this reorganization will be to appoint subcommittee secretaries and then obtain subcommittee chairmen.

On the matter of data sheets, it was suggested that data sheets could be prepared on the properties of stainless clad steel, the fabrication of stainless clad steel, and the properties of titanium, ceramics, and plastics. Mr. Teeple felt that the data sheets could most logically result from TAPPI projects covering these fields. It also was brought out that the subject of evaporation tube corrosion might be considered for a TAPPI project.

With regard to "Project Discussions," Mr. Hopper pointed out that it was necessary to obtain some good papers for the next February meeting in New York. The first paper, which will be prepared by W. E. Henricks and W. C. Barnwell, will deal with corrosion problems in alkaline pulping other than digesters.

The second paper, by E. Scholz and H. B. Harris, will cover corrosion in neutral sulphite pulping.

A third paper on acid pulping will be requested from the Acid Pulping Subcommittee. Mr. Teeple will check with this committee and Mr. Hopper will check with G. E. Scofield of Rayonier.

A fourth paper on corrosion in pulp purification will be requested by Mr. Teeple from the Pulp Purification Subcommittee.

A fifth paper on overlay installation and corrosion problems in alkaline digesters will be handled jointly by Messrs. Innes, Dela Grange, and Cyr.

A discussion was held on the possibility of establishing some cost figures for corrosion in the pulp and paper industry. Mr. Hopper asked Dr. Mueller and Messrs. Kesler and Boyd to put their thoughts together on this matter and write him a letter. This subject might be another potential TAPPI project.

The insurance representatives on the committee indicated that there was a definite need to watch corrosion in continuous digesters, as they were doing, but it was too early to get information together for a technical paper. Discussions also were held on failures and explosions in recovery boilers, but it was suggested that this might not be within the scope of the Corrosion Committee.

Discussions were held on the interchange of corrosion information between mills. It was pointed out that some of this information was already being gathered, particularly on digester corrosion, in the annual survey. Many mills will not reveal complete details on cooks, compositions of liquors, etc., because much of this information is considered a trade secret.

Mr. Hopper asked all members from allied industries if they would be agreeable to accepting jobs as subcommittee secretaries. None of the members present indicated that they could not accept such posts, so it is assumed that they are available at the discretion of the committee chairman.

The following motion was presented by the secretary, duly discussed, and unanimously accepted by the members present:

Motion: Any member of the Corrosion Committee who misses two consecutively scheduled meetings without legitimate excuse from the Corrosion Committee chairman will be dropped automatically from committee membership."

This motion was specifically presented and accepted in an effort to eliminate inactive members or members who cannot find time due to the press of other duties to attend committee meetings.

The meeting was officially adjourned by Mr. Hopper, after which a short steering committee meeting was held.

Minutes of Steering Committee Meeting

The following Corrosion Committee members were present for a short meeting after the general meeting: Messrs. Hopper, Cyr, Stamm, Dela Grange, Canavan, Mueller, Barnwell, Whitehead, Henricks, Kesler, Parker, Scholz, Hammond, and Harris. The purpose of this meeting was to review and consider the selection of a vice-chairman for the Corrosion Committee and chairman and secretaries for the subcommittees.

H. B. Harris, Jr., accepted the vice-chairmanship of the Corrosion Committee, subject to approval of his company. Mr. Hopper later contacted Mr. Leintz and obtained this approval.

Neither Mr. Barnwell nor Mr. Henricks felt he could take on the chairmanship of the subcommittee on Alkaline Pulping. Another person was suggested and Mr. Hopper will follow this lead.

Two men were suggested as possible chairmen for the Subcommittee on Pulp Purification: (1) R. Wheless, Union Bag-Camp Co., Franklin; (2) A. Stafford, Reigel Paper Corp., Carolina Div.

R. C. Stamm accepted the chairmanship of the Alkaline Digester and Overlay Subcommittee.

It was agreed that, upon obtaining a full slate of chairmen for the subcommittees, Mr. Hopper would appoint a secretary for each.

Our thanks go to R. B. Kesler for takimg notes during the meeting of the steering committee.

Harry W. Fritts, *Secretary*

TAPPI Corrosion Committee Members

S. J. Baisch, S. J. Baisch Associates, Kaukauna, Wis.
W. C. Barnwell, Crown Zellerbach Corp., Gaylord Div., Bogalusa, La.
Z. S. Blanchard, The Portland Co., Portland, Me.
W. K. Boyd, Battelle Memorial Institute, Columbus, Ohio.
A. O. Caldwell, Service & Erection Co., Pittsburgh, Pa.
H. M. Canavan, Mutual Boiler & Machinery Ins. Co., Waltham, Mass.
M. E. Cyr, Fraser Co.'s Ltd., Newcastle, N. B., Canada.
R. A. Davis, Chicago Bridge & Iron Co., Birmingham, Ala.
R. E. Gackenbach, American Cyanamid Co., New York, N. Y.
W. G. Gerstacker, National Annealing Box Co., Washington, Pa.
H. B. Harris, Jr., Union Bag-Camp Corp., Savannah, Ga.
C. W. Hayden, The Hayden Wire Works, West Springfield, Mass.
W. E. Henricks, Mead Corp., Chillicothe, Ohio.
J. T. Herlihy, Sandusky Foundry & Machine Co., Sandusky, Ohio.
E. G. Holmberg, International Nickel Co., Inc., New York, N. Y.
E. W. Hopper, *chairman*, Pittsburgh, Pa.

R. L. Horst, Jr., Aluminum Co. of America, New Kensington, Pa.
D. Innes, International Paper Co., Mobile, Ala.
L. K. Keay, Lukens Steel Co., Coatesville, Pa.
R. B. Kesler, The Institute of Paper Chemistry, Appleton, Wis.
A. R. Meyer, Graver Tank & Mfg. Co., East Chicago, Ind.
F. P. Morrison, Penobscot Chemical Fibre Co., Oldtown, Me.
J. B. Morrison, Crucible Steel Co., Waltham, Mass.
W. A. Mueller, Pulp and Paper Research Institute of Canada, Montreal, Que., Canada
W. B. Parker, Hartford Steam Boiler Inspection & Insurance Co., Hartford, Conn.
E. M. Read, Jr., Longview Fibre Co., Longview, Wash.
S. I. Reames, Hudson Pulp & Paper Corp., Palatka, Fla.
W. A. Rodowski, Kaukauna, Wis.
M. A. Scheil, A. O. Smith Corp., Milwaukee, Wis.
G. E. Scofield, Rayonier, Inc., New York, N. Y.
D. T. Smith, Jessop Steel Co., Washington, Pa.
R. C. Stamm, West Virginia Pulp & Paper Co., New York, N. Y.
B. Thomas, Stebbins Engineering & Mfg. Co., Watertown, N. Y.
A. Tirado A., Fabrica Celulosa, Tlalpan, Mexico, D. F.
H. T. Vardeman, Southland Paper Mills, Inc., Lufkin, Tex.
T. R. B. Watson, Corrosion Service, Ltd., Toronto, Canada.
F. D. Whitehead, Jr., West Virginia Pulp & Paper Co., Covington, Va.
J. M. Wilcox, Electric Steel Foundry Co., Portland, Ore.
P. G. Zouck, Alloy Cladding Co., Inc., Baltimore, Md.

Electrical Engineering Committee

The Electrical Engineering Committee met Oct. 13, 1959, at Pittsburgh, Pa. Members present:

R. F. Sorenson, *chairman*	C. L. Harvey
I. Witham, *vice-chairman*	R. J. Minges
G. E. Shaad, *secretary*	L. D. Mower
S. Andersen	M. J. Osborne
H. B. Barrow	G. L. Oscarson
S. A. Bobe	E. G. Parrish
P. C. Bobo	Malcolm Perkins
N. L. Danforth	D. C. Pier
R. J. Farrell	L. W. Porter
J. F. Fenske	M. M. Stokely
M. H. Fisher	H. W. Thompson
R. W. Foster	H. A. Wright

Members absent:

D. E. Bivins	N. D. Kenney
James Cundelan	L. J. Randall
C. G. Herrington	J. K. Walsh

Guests present:

J. G. King	A. L. Mortenson
S. J. Campbell	P. W. Clark

Immediately following the committee luncheon, the meeting was called to order by Chairman Sorenson. Attending guests, Messrs. Mortenson, Campbell, King, and Clark, were welcomed to the meeting.

The change in committee chairmanship effective at the end of the Engineering Conference was announced. Mr. Andersen will replace Mr. Sorenson as chairman. The resignation of Mr. Witham as vice-chairman was also announced with a new vice-chairman to be designated at a later date.

Mr. Bobe reporting for the Generation and Distribution Systems Subcommittee reported that the material for the monograph on paper mill power systems had been given to Mr. Teeple for processing. In the opinion of the subcommittee, the best work of the subcommittee would be in the area of providing authors and papers on timely subjects rather than detailed mill studies. Data sheets were considered generally unworkable for this subcommittee although some sheets providing bibliographies or general power requirement estimates may be desirable. Mr. Shaad is to review the possibility of providing estimating power consumption values for general mill areas and report to the subcommittee.

Mr. Bobe proposed a paper on "Mill Operation with Purchased Power" for the 1960 conference with joint authorship

Electrical Engineering Committee

by a mill man and a representative of the utility supplying the mill.

Mr. Andersen reported for the Publicity Subcommittee that the primary publicity had been in *Tappi* with considerable material being included in both the May and August issues. He also advised that the next issue would include the report on butyl rubber insulation and that he had agreement from Mr. Eletson to provide a condensation of Mr. Eletson's paper on a "Do-It-Yourself Short Circuit Board."

Mr. Andersen reminded the committee that the "Question and Answer" column is a monthly feature in which electrical questions have been quite prominent. It is necessary, however, for the committee to actively solicit additional material. Such questions need not include answers, but may include answers if it appears desirable.

In connection with the publication of material, Mr. Andersen advised that he had encountered some problems with the magazine but had hopes that they would be cleared in the near future.

Mr. Foster reporting for the Construction Materials and Methods Subcommittee advised that their subcommittee had not been as active as was desirable, but that the subcommittee would hold a meeting immediately following the committee meeting to review their projects and the actions to be taken. The active projects under consideration were to bring the cable data sheet up to date, provide additional comparative figures on the cost of installation of cables in trays and a presentation of cable material corrosion results representing a series of studies that have been made by Champion Paper and Fibre. Mr. Foster advised that added mill personnel were desired for this subcommittee.

Mr. Bobo reporting for the Drive Requirements—Finishing and Converting Subcommittee advised that no specific action had been taken since the June meeting but that a committee meeting was scheduled immediately following the committee meeting.

The Drive Requirements—Pulp Mill Subcommittee had held no meetings and presented no report.

Mr. Minges reported as follows on activities of the Drive Requirements—Paper Mill Subcommittee:

Project No. 620. Power Requirements of Feltless Pulp Machines. This report is in review by the subcommittee. Unless adverse comments are received by November 15, the report will stand approved. Mr. Minges noted the questionnaire approach on this project, where questionnaires applying to specific machines were sent out to the mills, and answers received from 11 of the 15 mills.

Project No. 621: Power Requirements of Structural Board Machines. Under this project they presently have information on seven machines with information on three more

machines expected. There is apparently no correlation as to the power requirements of the various machines with an indication that all drives are appreciably overmotored. This project will be reviewed in detail and a report will be available at the interim meeting to be held in the spring.

Project No. 783: Revision of Data Sheets 145A, B, C, and E. Review of these data sheets indicated that the material is covered by power constants and information contained in TAPPI Data Sheet 145G (as revised by Project No. 358). The subcommittee recommended that these four data sheets be cancelled and this action was approved by the committee.

Project No. 782: Examples of the Use of Power Constants had had no action as a result of misunderstanding.

Project No. 622: Power Requirements of Tissue Machines. Project committee meeting is to be held on this project with the expectation of revising the questionnaire into an acceptable form and establishing a list of 15 to 20 tissue machines on which to base the study. It is expected that a status report will be presented at the interim meeting next spring.

A questionnaire regarding the subjects of interest for future subcommittee activity was distributed to all subcommittee members to establish subjects for future activity. Mr. Minges noted that one subject of particular interest was the power requirements of the new high velocity air driers.

Mr. Parrish reported that the Motors, Generators, and Control Devices Subcommittee was getting off to a relatively slow start but had under consideration three main subjects. The subjects in mind were the power requirements for refining equipment, power requirements for washers, deckers, and vacuum filters, mill experience with sealed insulation systems; and motor bearing problems encountered with flexible couplings. In addition, Mr. Parrish suggested a paper with the "Instrumentation Systems" and suggested to the Steam and Power Committee that they emphasize a paper on centralized control systems.

General committee discussion brought out the fact that two of these subjects, power requirements of refining equipment and power requirements of washers, deckers, and vacuum filters, were the responsibility of the pulp mill subcommittee and should be referred to Mr. Herrington. Mr. Andersen will write to Mr. Herrington and get these projects under active consideration.

In connection with these two projects, it was noted that the machinery builders were actively interested in any work being undertaken on such projects. It was expected that all interested machine builders would be invited to participate in such projects.

Mr. Perkins reporting for the Personnel Subcommittee advised that the subcommittee was extremely short of mill personnel and would appreciate help from the committee in obtaining additional membership for this subcommittee. A short subcommittee meeting was held in June with considerable discussion as to the best subcommittee operations. In general, it appeared that procurement and selection of personnel were handled by other areas of the mills and the subcommittee was still studying the best area on which to work.

General discussion by the committee suggested concentration on organization and training. Training in particular was a major problem to many mills. Good papers on training and organization were very desirable.

A general discussion of the survey made some years ago on mill organization, did not provide any "standard answer" for the number of men or organizational arrangement of various mills. This is apparently an area which will vary widely, depending on the particular mill involved. Broad fundamental suggestions however could be helpful in reviewing mill operations.

Mr. Stokely reporting for the Membership Subcommittee, advised that J. K. Walsh of Union Bag and Paper has been added to the committee membership. It was also announced that Mr. Fisher expects to design from the committee because of other duties and Mr. Osborne must resign as a result of being chairman of the Engineering Division. Mr. Campbell will replace Mr. Fisher on the committee and it is expected that a replacement will be available for Mr. Osborne.

The projects that were not covered in subcommittee reports were reviewed as follows:

Project No. 368: Power Requirements of Supercalenders. This project is to be closed out for the final report has been presented by Mr. Farrell.

Project No. 657: Recommended Maximum Voltage Levels for A.C. Motors. Data sheet on this project has been sent to the review board and this project is closed.

Project No. 677: Use of Butyl Rubber Cable in Pulp and Paper Industry. This report has been given *Tappi* for publication and the project is closed.

Project No. 686: Medium Voltage Control. General report and specifications have been given and the project is to be closed.

Project No. 739: Effect of Specific Speed Torque Characteristics on Pump Motor Selection and Operation. Data sheet covering this material has been given to the review board and the project is closed.

Project No. 740: Winder Drive Power Requirements. Preliminary report has been given by Mr. Fisher. This report will now be circulated to the committee for approval and the preparing of data sheets.

Project No. 746: Barking Drum Drive Requirements. Data sheet on this project has been sent to the review board and this project is closed.

The papers for the 1960 Engineering Conference at Jacksonville were discussed and the following papers were selected:

"Ventilation of Motor and Control Rooms" by R. F. Sorenson.

"Electrical Considerations in the Use of Purchased Power," Paper to be jointly authored by a mill man and a utility man. Authors to be obtained by Mr. Bobe.

"Motor Thrust Conditions Encountered with Gear Type Flexible Couplings." This paper to be presented by a coupling manufacturer with the author to be obtained by Mr. Parrish. (A tentative author has been obtained, but this will be confirmed by Mr. Parrish.)

Discussion panel on "Motor Thrust Conditions Encountered with Flexible Couplings." Panel members are to be obtained by Mr. Parrish's subcommittee and will include mill personnel, coupling manufacturers, and motor manufacturers.

A general discussion of the conference operations indicated some interference between meetings being held on subjects of like interest. It was suggested that every effort be made in future schedules to keep this conflict at a minimum.

Mr. Sorenson closed the meeting with an expression of appreciation to Mr. Witham for his work with the committee, and Mr. Osborne for his past work with the committee. He expressed his appreciation of the considerable amount of activity by the subcommittees and recommended that they place emphasis on interim meetings at which time they can actively plan and schedule their project work.

G. E. Shaad, *Secretary*

Industrial Engineering and Materials Handling Committee

The Industrial Engineering and Materials Handling Committee as usual had a most active part in the 14th Engineering Conference at Pittsburgh, Pa. The luncheon meeting was held on Monday, October 12 and the committee program was held on Wednesday, October 14.

In attendance at the luncheon meeting were Chairman Kendall, Secretary Stoess and members: Green, Parker, Patch, Kemp, MacBrayne, Sweitzer, Schnyder, and Sweers. We were honored by the attendance of H. G. Ingraham,

Industrial Engineering and Materials Handling Committee

chairman of the Data Sheets Committee. The meeting was called to order by Chairman Kendall at 12:30 p.m.

Data Sheets were first discussed, and as usual at conferences, not much was accomplished on this subject. Since a most successful interim meeting was held last May, it was decided to hold another, this time in New York instead of Philadelphia. Upon a motion by Mr. Green, seconded by Mr. Parker, the secretary was instructed to set up and arrange this meeting, preferably late November or early December. Mr. Ingraham is to be kept informed.

Next, our past chairman, J. M. MacBrayne gave a most heartwarming tribute to Dan Patch, upon his retirement from TAPPI and our committee. As a token of the esteem in which Dan is held, a desk pen set was given him by the members of the committee. Words of appreciation were then given by Dan.

A letter of resignation from R. F. Betts was read by the secretary. Upon the motion of Mr. MacBrayne and seconded by Mr. Parker, the resignation was accepted with regrets. The secretary was instructed to write Mr. Betts of our action. R. W. Sweitzer Link Belt Co., was then elected to the committee to replace Mr. Betts.

The program for the 15th Engineering Conference at Jacksonville in October, 1960 was discussed and plans completed. First, a panel discussion on finishing room operations with members of the panel from Continental Can, Union Bag-Camp and Crown Zellerbach, and second a paper on clay handling and storage by H. A. Stoess.

Returning to the subject of Data Sheets, it was decided to have a vice-chairman of this subcommittee. Creed Reagan of Union Bag-Camp at Savannah, Ga., was appointed.

The secretary is sorry to report a mishap by Marjorie and Fil Wilson on the road to Pittsburgh. Their car skidded off the road in Virginia and fortunately they escaped injury.

The program of the committee was held on the morning of October 14 with the attendance varying from 46 to 125. The first paper on industrial enginerring was ably presented by J. E. Angle, a vice-president of the U. S. Steel Corp., and the second paper was equally well presented by R. D. Owen of Glatfelter's at Spring Grove, Pa., on broke handling. A short question and answer period followed the presentation of each paper.

At the Division Luncheon on Wednesday, October 14, J. R. Lientz, president of TAPPI, presented an award for meritorious service to TAPPI to Dan Patch. Jim surprised Dan with the award, which was for a lifetime of service to the technical work of the pulp and paper industry, and particularly his furtherance of the work of the Engineering Division. Dan has attended each and every Engineering Conference held to data, a record in itself. This was the first of these special awards to be given since they were authorized by the Executive Committee last February.

Respectfully submitted,
H. A. Stoess, Jr., *Secretary*

Mechanical Engineering Committee

The Mechanical Engineering Committee met for luncheon on Tuesday, Oct. 13, 1959, at 12:30 p.m., in the Park View Room of the Hotel Penn-Sheraton, Pittsburgh, Pa. Chairman M. N. Davis presided. Fourteen members and five guests were present, listed as follows:

R. W. Brown, Fitchburg Paper Co.
J. W. Crocker, Stowe & Webster Eng. Co.
J. R. Curtis, Scott Paper Co.
M. N. Davis, Kimberly-Clark Corp.
P. A. Fasoli, C. H. Dexter & Sons
W. F. Fields, Armstrong Cork Co.
P. H. Goldsmith, Dominion Eng. Works
J. C. Harper, Rice Barton Corp.
C. E. Hill, West Virginia Pulp & Paper Co.
B. M. Hutchins, Rust Engineering Co.
H. G. Ingraham, Chas. T. Main, Inc.
D. E. Jones, E. D. Jones Corp.
R. A. Jordan, Great Northern Paper Co.
J. S. Mudgett, Strathmore Paper
A. L. Pickens, Buckeye Cellulose
R. U. Saulter, The Torrington Co.
G. H. Spencer, The Torrington Co.
S. W. Widmer, The Torrington Co.
G. F. Wright, Black-Clawson Co.

Chairman Davis opened the meeting by commending the speakers at the Fifth Conference Session on Monday, October 12. C. E. Hill spoke on extensible-paper machinery; W. F. Fields spoke on improvements in pulpwood grinders; and H. A. Smith spoke on horizontal size presses. Mr. Davis expressed the thanks of the committee to these speakers for their excellent presentations and reported many favorable comments have been received. The average attendance at the Mechanical Engineering session was 175 people.

Reports of Subcommittees:

Wood Preparation. Chairmanship vacant. No report.

Pulp Preparation. Chairman R. T. DePan absent. No report.

Paper Manufacturing. Chairman J. W. Crocker reported briefly on the activities of this subcommittee. A meeting was held on October 12 at which time the project on paper machine vacuum pump requirements was discussed at considerable length. Mr. Crocker plans to submit a detailed written report in the near future. It is expected that this project will produce vacuum pump data sheets at an early data which should be a welcome offering to the Data Sheet Committee.

Finishing and Converting. Chairman R. W. Brown. No report.

Data Sheets. Chairman P. H. Goldsmith. It was called to the attention of the committee that the two functions of this subcommittee are to provide papers and data sheets which will be revised by the committee as a whole. It is to be noted in this connection that at our last meeting in New York the impetus was given to start the work on vacuum pumps by the Paper Manufacturing Subcommittee mentioned previously.

J. R. Curtis addressed the group briefly as a representative of the Engineering Division Staff Advisory Committee. In his remarks he mentioned the advisability of forming a steering committee to regulate the govern the committee activities.

G. W. Spencer made a motion, unanimously approved, that a steering committee of four members be appointed by the chairman to plan and schedule committee projects, to define the scope of the subcommittees and to direct the production of technical papers and data sheets.

Chairman Davis advised that there will be an interim meeting of the full committee early in January at TAPPI headquarters in New York, definite data to be advised later. The purpose of this meeting will be to plan our program for the

15th Engineering Conference in Jacksonville, Fla., Oct. 24–28, 1960.

Arrangements for review of conference papers by all members prior to the meeting will be discussed at the next meeting.

P. H. Goldsmith requested that more satisfactory arrangements be made for review of Data Sheets. It was decided that he should submit such material to the appropriate subcommittee chairman who will then get in touch with his subcommittee members.

C. H. Spencer advised that as a member of the Question and Answer Committee for *Tappi* he plans to send copies of all pertinent questions to all committee members for comment.

H. G. Ingraham suggested that the proposed review of previous papers be taken care of by the newly formed Steering Committee.

C. W. Crocker announced that he is resigning as chariman of the Paper Manufacturing Subcommittee and that C. E. Hill has accepted the chairmanship.

G. F. Wright offered a technical paper on calender stacks to be presented at the next conference by someone yet to be named. This offer was referred to the Paper Manufacturing Subcommittee.

A motion of confidence in the leadership of this committee was unanimously passed by all present, and was gratefully acknowledged by Chairman Davis in behalf of all those who have contributed their assistance to him.

Meeting adjourned at 1:45 p.m.

J. C. Harper, *Secretary*

Steam and Power Committee

At the 14th Engineering Conference, the Steam & Power Committee:

1. Sponsored a three-hour technical session.
2. Held a committee luncheon, whose work was supplemented by a specially called meeting of the committee on the following afternoon.
3. Held an authors' breakfast before the main technical session.

In addition, a session of interest to those associated with the steam and power phases of the pulp and paper industry was one sponsored by the Westinghouse Electric Corp., which included a film on "Construction and Operation of the Shippingport, Nuclear Generating Station" and also a short résumé on a symposium recently sponsored by AEC on the subject of "Nuclear Energy for Process Heat."

Technical Session

R. V. Knapp was chairman of our technical session held in the Urban Room beginning at 9:15 a.m. on Monday, Oct. 12, 1959. Attendance during the "papers" portion of this session ranged up to about 190 people. The papers were:

1. "Progress Report on Atomic Power," by J. H. Wright and J. W. Magee.
2. "Equitable Allocation of Costs for Process Steam and Electric Power in Paper Mill Power Plants," by G. D. Farrar.

In the panel discussion which followed, J. G. Hoad was moderator, with an audience of 155 people. The subject of this panel discussion was "Economic Aspects of Pressures and Temperatures for Pulp and Paper Mill Power Plants."

The discussers included:

A. Turbine Generators, by I. H. Landes.
B. Power Boilers, by H. B. Wallace, Jr.
C. Recovery Boilers, by W. J. Darmstadt and F. W. Hochmuth.
D. Mill Experience, by T. J. Judge.

This Steam and Power Session had the highest attendance of any session to date. Based on various comments from those who attended the session, the presentations were very well done and the subject matter was of particular interest to a very large segment of those attending the conference. It is expected that all these papers will be published in *Tappi*.

Committee Luncheon and Specially Called Meeting

The Steam and Power Committee's luncheon held in the Sky Room of the Penn-Sheraton Hotel on Oct. 13, 1959, was attended by 18 committee members and 6 guests. Members present:

H. R. Arnold, Continental Can Co.
F. H. Coldwell, Nekoosa Edwards Paper Co.
M. Ellis, Continental Can Co.
H. R. Emery, St. Regis Paper Co.
G. B. Gregg, Cincinnati Gas & Electric
J. G. Hoad, John G. Hoad & Associates
J. E. Hoeft, Owens-Illinois
R. V. Knapp, Mosinee Paper Mills Co.
L. Limon, Graver Water Conditioning
P. L. Nelson, Charles T. Main, Inc.
C. R. Podas, Pfeifer & Shultz
B. M. Turner, International Paper Co.
H. B. Wallace, Jr., Foster Wheeler Corp.
C. L. Wills, Halifax Paper Co.
T. Woodward, Scott Paper Co.
W. M. Wyburn, Federal Paper Board Co., Inc.
G. L. Yeakel, Gilbert Associates
W. B. Wilson, General Electric

Guests present:

R. W. Boberg, Scott Paper Co.
C. C. Bush, Union Bag-Camp Paper Corp.
W. J. Darmstadt, Babcock & Wilcox
V. P. Owens, Combustion Engineering, Inc.
W. C. Rindsland, Minnesota and Ontario Paper Co.
R. H. Sogard, Mead Corp.

R. V. Knapp announced that he was retiring as chairman of our committee and introduced the incoming chairman, H. R. Emery, and the incoming vice-chairman, C. L. Wills. Mr. Knapp also introduced our guests and mentioned that many of these were interested in becoming working members of our Steam and Power Committee. Mr. Knapp's contribution to TAPPI and the Steam and Power Committee was acknowledged on Wednesday at the Engineering Division Luncheon. J. R. Lientz, TAPPI president, presented TAPPI's Certificate of Appreciation to Mr. Knapp.

It was announced that the 15th TAPPI Engineering Conference will be held in Jacksonville, Fla., on Oct. 24–28, 1960. The 1961 conference will be held in Washington, D. C., and the 1962 conference in Montreal, Canada.

Additional Committee Activities

H. R. Emery reported on the replies he had received to his Apr. 9, 1959, letter to all members of the Steam and Power Committee on the subject of "Additional Activities." Little more than half (not very good) of our committee members had replied to Ross's letter. In the replies that have been received, there seemed to be general agreement that the mills have not properly integrated their power thinking with thoughts on new process developments. Those attending the meeting seemed very much interested in a closer working relationship between the steam and power group and the process development group so the effect of any changes in process can be properly factored into plans for the over-all steam and electric power system. All recognize that changes in process which affect the quantity or the pressure of steam required in process have a marked effect on the optimum operation of a steam and power system.

The second idea was for a bibliography which might or might not include a short explanation of the material available in different articles relating to the steam and power system. TAPPI's present bibliography of papermaking and U. S. patents includes a section on steam and power, but I am not at all sure how complete this coverage is intended to be.

A third suggestion was the idea of having a subcommittee gather and distribute published data.

Another suggestion was that of reporting on new develop-

ments in power plant equipment each year. There was some feeling that a summary paper on this subject each 3, 4, or 5 years might be as frequently as this kind of material could be expected.

A short discussion followed as to the most logical method of presenting this material. Different ideas included: (1) multilith for general distribution, distribution to committee, or to all registrants at the Engineering Conference; (2) print in *Tappi;* (3) have a short presentation at each Steam and Power Session.

Mr. Emery concluded this discussion by welcoming any additional comments that people might wish to send to him and proposed that he would review the various ideas suggested for a more detailed discussion at our spring committee meeting.

Subcommittee Reports

The general objectives and status of the various subcommittee projects are tabulated below:

Annual Listing of Power Plant Equipment in Industry (*Project 681*). Subcommittee Chairman, Earl Donley.

Objective: Annual compilation of power plant equipment supplied to the pulp and paper industry.

Status: Continuing project. Published annually in *Tappi*. The last data was published in *Tappi* in December, 1958. At our Chicago meeting last spring, it was agreed that the tabulation would be broken into two sections—"Before Operation" and "After Operation." It was also planned to indicate by an asterisk which entries had been included in previous published reports. With these breakdowns, Mr. Donley feels that publication each two years may be sufficient.

Training of Power Plant Engineers (*Project 682*), Subcommittee Chairman, T. Woodward.

Objective: Document suggested methods of training power plant personnel.

Status: Termination as panel presentation at 1960 Engineering Conference.

Steam and Power Consumption (*Project 683*), Subcommittee Chairman, John G. Hoad.

Objective: Establish data on steam and power consumption in various phases of pulp and paper production.

Status: Questionnaire being prepared for accumulating data from mills, etc.

Engineering Data Sheets (*Project 684*), Subcommittee Chairman, P. L. Nelson.

Objective: To review existing and provide new data sheets applicable to steam and power problems in pulp and paper industry.

Status: Those data sheets assigned for review have been reviewed. New data sheets and guide sheets are in process. Expect a series of "Power Piping Specifications" to be ready for review soon.

Progress in Nuclear Power (*Project 726*), Subcommittee Chairman, H. B. Wallace.

Objective: To keep committee informed of nuclear developments affecting the application of nuclear energy for industrial steam and/or power generation.

Status: Paper at 14th Engineering Conference devoted to "Progress Report on Atomic Power."

Question and Answer Section for Tappi, Subcommittee Chairman, J. E. Mailhos.

Objective: To provide *Tappi* sufficient technical material so a continuing "Question and Answer Section" can be maintained under the TAPPI Engineering Division masthead.

Status: This is a continuing project, and each committee member should make a sincere effort to mail suitable questions to Joe Mailhos. To get this project under way, we hope you will be able to mail both the question and the answer for some problem that you may have had which would be of general interest to *Tappi's* readers. If you have a question, but do not have the answer, why not send this to Joe also.

Technical Papers Review, Subcommittee Chairman, C. R. Podas.

Objective: To review Steam and Power Committee sponsored papers and to maintain the highest quality possible.

Status: This subcommittee will function in connection with papers scheduled for the 1960 Engineering Conference. It is a new committee which has not been in place for previous conferences.

Publicity, Subcommittee Chairman, G. B. Gregg.

Objective: To publicize the activities of the Steam and Power Committee.

Status: This, of course, is a continuing project, and Mr. Gregg would welcome ideas and suggestions from all committee members as to how publicity can be handled more effectively. TAPPI Headquarters retained a firm to handle much of this work for the Pittsburgh conference.

Committee Scope

TAPPI Headquarters request a periodic review of committee scope. A discussion of our present scope at this committee luncheon indicated that no revisions were desired at this time.

The committee scope which we approved last year and identified as W-58-9 revised by W. B. Wilson, Nov. 26, 1958, will be included in the TAPPI Engineering Division Operating Manual. To get a condensed version of this for publication in TAPPI's Yearbook, some of the explanatory material was eliminated. A copy of our more complete scope, follows these minutes.

One Versus Two Steam and Power Sessions

There seems to be a reasonable back-log of popular topics for technical papers that could be scheduled at the annual engineering conference. Because of this, the question was raised at our interim committee meeting in Chicago as to whether or not the Steam and Power Committee should request more than a single 3-hr. session at the annual engineering conferences. Consensus of those present at the Chicago meeting was that one session at each engineering conference would be adequate.

The general consensus seems to be that the general quality of our sessions might deteriorate if we attempt to get material prepared for two sessions. I think all agree that one good session will be much better than two mediocre sessions.

No action was taken on this matter at the Pittsburgh meeting. If the need arises for additional time at the engineering conference, the committee can handle it when the occasion arises.

The question of additional technical sessions versus the continuance of mill tours is one possibility of getting more time for technical sessions. It was agreed that some areas provided excellent mill tour opportunities and others would provide tours of less interest to TAPPI membership. The Steam and Power Committee feels that TAPPI Headquarters can best decide on the need for mill tours.

Another avenue for making additional technical material available to our membership is the publication of technical papers in *Tappi*. The Steam and Power Committee can sponsor papers for printing in *Tappi* when suitable papers are available even though they may not be presented orally at a technical session.

Interim Committee Meetings

The major work session planned for the over-all committee is still at our interim spring meeting. The committee will be polled for the date and time for this meeting.

It is possible that some subcommittees may want to sched-

ule time for meetings just prior to the over-all committee meeting.

In the past, the committee has had an informal get together during the annual TAPPI meeting in New York during February. No formal work has been scheduled at this meeting because of the small number normally in attendance. Because of this, no breakfast or luncheon meeting is planned during the February TAPPI conference.

Specially Called Meeting

Even though our main papers and panel had been selected for the 1960 conference, a paper on operation of recovery boilers would be very timely because of a recent boiler explosion. Because of the widespread interest in the assignment of responsibility for operating recovery boilers, the special meeting of the committee was called to determine if this timely subject should be scheduled for the 1960 Engineering Conference. A total of 14 was present at the special meeting, and this group was in unanimous agreement that a paper entitled "Why Operation of Recovery Boilers Should Be the Assigned Responsibility of the Power Department," authored by H. R. Arnold, should be scheduled instead of the previously scheduled paper on "Outdoor versus Indoor Power Plants."

In general discussion on the problem of recovery boiler operation, there seems to be different opinions on safe procedures for shutdown of these boilers depending on whether subject is being discussed with mill people, insurance companies, or different boiler manufacturers. It was suggested that the Steam and Power Committee might consider setting up a project which would study over-all instructions and practices in recovery boiler operation. This study team might consist of boiler people, mill people, and possibly insurance people.

1960 Program

The fifteenth TAPPI Engineering Conference is to be held Oct. 24–28, 1960, at the Hotel Robert Meyer in Jacksonville, Fla. The program selected for the Steam and Power Committee's session is:

Papers:

"Water Treatment for Boilers Opeating in the 600 to 1250-lb. Range with High Make-up," by Leonard Limon, Graver Water Conditioning, and R. A. Dando, St. Regis Paper Co.

"Why Operation of Recovery Boilers Should Be the Assigned Responsibility of the Power Department," by H. R. Arnold, Continental Can Co.

Panel Discussion:

"Training of Power Plant Personnel," Panel Moderator, T. Woodward, Scott Paper Co. Mr. Woodward is now completing plans and selecting members for this panel discussion.

1961 Program

The 16th TAPPI Engineering Conference is scheduled for Washington, D. C., in 1961. A list of several topics is already available to chose from and the committee will be polled very soon for additional, timely subjects so the 1961 program can be well along by the time of the spring interim committee meeting.

Author's Breakfast

At a breakfast held in the West Room on Monday morning, October 12, the authors and panel members were given the opportunity to meet their session chairman and others who were to participate in the program.

We were glad, as always, to have Vince Owens meet with the group, and a total of 13 attended the breakfast.

Of course, another reason for the breakfast is to be sure there has been a clear understanding and provisions for equipment that authors require. The authors had previously forwarded these data, together with their biographical sketches, to the session chairman. This permitted full utilization of the time for getting acquainted and enjoying our breakfast.

New Members

We have several candidates for new membership on the Steam and Power Committee and membership application forms are being mailed to existing members as well as prospective new members. As soon as membership application forms are returned and approved, a new list of committee membership will be issued.

W. B. Wilson, *Secretary*

Scope of TAPPI Steam and Power Committee

The Steam and Power Committee's function in TAPPI's Engineering Division is to:

I. Do the research and study necessary for the preparation of papers, special reports and data sheets covering pertinent information and recommendations relating to:

A. The specification, application, installation, operation, and maintenance of:
   1. Steam generating equipment including waste fuel and chemical recovery units.
   2. Steam distribution and condensate system throughout the mill.
   3. All prime movers and their place in the over-all mill heat balance when used for generator, paper machine, or other mechanical drive applications.
   4. Electric power generators, except for electrical design features.
   5. Auxiliary equipment, such as pumps, fans, instrumentation, and the water supply and water treatment associated with and necessary for operation of the mill's steam and power system.

B. Over-all mill steam and electric power requirements as a guide in planning facilities for different types of new mills or mill expansions.

C. The specification, storage and utilization of all fuels, including nuclear energy, and the disposal of ash and spent fuel.

II. Coordinate with other TAPPI committees to be sure our activities are coordinated to eliminate duplication of effort.

III. Keep informed on the activities of other technical associations and engineering societies to be sure that use is made of all available information related to the Steam and Power Committee's activities.

Corrugated Containers Division—Production Committee

The Production Subcommittee of the Corrugated Containers Committee held a meeting at the Jung Hotel, New Orleans, La., on Sept. 15, 1959, from 2:00 to 5:30 p.m.

Present were:

Douglas Adams, St. Regis Paper Co., Canton, Ohio.
Loren F. Ashwood, Downing Box Co., Milwaukee, Wis.
Donald Blackburn, Martin Paper Products Ltd., Winnipeg, Man., Canada.
Ralph W. Buttery, Bathurst Containers Ltd., Montreal, Que., Canada.
Dave C. Dowd, Specialty Equipment Corp., Worcester, Mass.
Charles E. Hill, West Virginia Pulp & Paper Co., Covington, Va.
W. J. Hurrell, Hinde & Dauch Paper Co., Toronto, Ont., Canada.
D. T. Jordan, Hygrade Containers, Ltd., East Montreal, Que., Canada.
W. S. McDonald, International Paper Co., Georgetown, S. C.
Burt Mendlin, Cornell Paperboard Products Co., Milwaukee, Wis.
Keith Provo, Gaylord Container Corp., St. Louis, Mo.
Cam Reid, Pembroke Shook Mills, Ltd., Pembroke, Ont., Canada.
Joe Simpson, St. Regis Paper Co., Cleveland, Ohio.
Harry W. Wilson, Royal Container Co., San Francisco, Calif.

Project No. 695—Adhesives Factors. Nine companies have now reported to Mr. Blackburn, and all are preparing their figures properly. All data should be presented by the February meeting so that this may be turned over to the University of Manitoba with a minimum of 200 observations for each plant.

Corrugated Containers Division: Production Committee

From the results of this preliminary information, the committee will determine how to proceed, if at all, with the project.

Project—Supervisory Training. A sample study plan on handling grievances was presented by Mr. Ashwood. The committee approved this approach, suggesting that future study plans include the amount of time that should be allotted for each session and the recommended frequencies of such meetings.

Should Mr. Williams be unable to continue on the subcommittee, Mr. Provo volunteered to assist. Accordingly, study plans will now be prepared on: human relations, 3 hr; costs, 3 hr; quality, 3 hr.; waste, 3 hr.; safety, 2 hr.; union contract, 2 hr.; company policy, 1 hr.; methods, 1 hr.; errors, 1 hr.; and communciations, 1 hr.

Project No. 781—Errors. Mr. Jordan and Mr. Reid will assist Mr. Hurrell in preparing and circulating questionnaires to all committee members prior to the February meeting. The subcommittee was cautioned to carefully prepare the questionnaire so that it accomplishes the objectives desired and shows each participant how he might benefit from the information.

In a discussion on the objective of this program, it was brought out that the questionnaire should cover: a definition of errors, systems to record errors, causes of errors, means to measure the cost of errors relative to the number of items produced, etc., and methods of minimizing errors. It was pointed out that not only do errors needlessly cost money, but those which repeatedly exist in specifications tend to adversely affect morale and impair the relationship between plant and office personnel.

Project—Maintenance Costs. Because none of the members had either been successful in their own operations or were somewhat at a loss as to how to (1) assure accurate recording of maintenance time; (2) relate maintenance costs (or manhours) to some meaningful common denominator (production volume, sales dollar, production hours, etc.), it was decided that Mr. Provo will approach the Engineering Committee to see if they would be interested in investigating this subject.

New Projects. Mr. Buttery questioned if there were a successful way of correlating the amount of roll stock actually used with the amount received, taking into account the amount of waste produced. His company is attempting to use this to reduce waste. Mr. Provo reported that his company tries to correlate this information for better inventory control. No action was taken for a committee assignment.

Mr. Mendlin suggested that a study be made to determine the best and simplest group of accounting figures required by operating management to measure the performance in each center for past and future comparisons. Any value which might result for comparisons between plants and companies would be an extra benefit, principally the information should be very worth while to individual plant management. Discussion disclosed that one cannot compare the actual square footage produced relative to either costs or man hours, as these are good only if the figures are so modified to take into account the kind of product and the type of board being run. Each member was asked to send 15 copies of all control forms to Mr. Provo, who will then redistribute these to all members for review at the February meeting. It would help further if each member would indicate those particular figures which are the most meaningful to him in keeping his fingers on the performance. Blank forms with only the headings and minus the actual figures are all that are needed.

February, 1960, Meeting. Mr. Dowd announced that speakers were arranged for papers on: scheduling, errors, palletizing specifications, methods of measuring the amount and effect of colloidal silica, and the Owens-Illinois C flute profile. It is hoped that the balance of the program will be completed before the Fall Meeting is adjourned.

General. It was decided to revise the Engineering Division questionnaire and to each year require each member to sign a new one if he intends to continue to be active; otherwise failure to do so would automatically mean termination from the Production Committee.

It was agreed that the present officers would continue and that a nominating committee would be appointed at the February meeting.

LOREN F. ASHWOOD, *Secretary*

Corrugated Containers Division—Process and Quality Control Committee

The Process and Quality Control Committee of the Corrugated Containers Division held a meeting at the Jung Hotel in New Orleans on Sept, 15, 1959, at 2 p.m. The following members of the committee were present:

K. R. Martin, Olin-Mathieson Chemical Corp., *chairman*
H. W. Seibel, Gaylord Container Corp., *vice-chairman*
H. E. Dunholter, The Eastern Box Co., *secretary*
G. C. Lecky, F. J. Kress Box Co., Div. St. Regis Paper Co.
S. L. Goodrich, General Box Co.
L. Timmer, Mead Corp.
J. Baumgartner, Tenn. River Pulp & Paper Co.
T. D. Jones, Hoerner Boxes, Inc.
B. Q. Haynes, B. F. Perkins & Son.
D. M. Long, River Raisin Paper Co.
O. P. Wanamaker, Fibreboard Paper Products Corp.
W. Lindsey, Olin-Mathieson Chemical Corp.
N. U. Siddiqui, Standard Paper Box—Canada.
F. H. Albert, Menasha Woodenware Co.
H. J. Ostrowski, Hinde & Dauch—Canada.
D. Coder, Packaging Corp. of America.
G. S. Sourrielis, Owens-Illinois Glass Co.
C. J. Zusi, Consultant.
A. Schwartz, David Weber Co.
H. G. Nelson, Owens-Illinois Glass Co.
N. Varner, Union Bag-Camp Paper Corp.
A. W. Hoffman, Continental Can Co.
P. J. Cox, Consolidated Water Power & Paper Corp.

The following guests were present:

D. Welvin, Weyerhaeuser Timber Corp.
H. J. Schlotter, Hoerner Boxes, Inc.
C. A. Turk, Ortman-McCain Co.
J. Corcoran, Packaging Corp. of America.
H. B. Johnson, International Paper Corp.
W. B. Lincoln, Inland Container Corp.

Frank Albert, chairman of Project No. 761 entitled "Evaluation of Pin Adhesion Test" was asked to report on the progress of his committee. After considerable discussion, several members stated that the pin adhesion test was valuable as a routine control measure but was definitely not used as a standard for customers. Some agreed that it was a good diagnostic test for adhesive penetration.

Others stated that pin adhesion tests do not always show a good correlation—poor glue patterns sometimes show good pin adhesion and vice versa.

Corrugated Containers Division: Process and Quality Control Committee

Further discussion pointed out that the best pin adhesion tests were obtained at about 8% moisture content of the board. Dry board showed low pin adhesion. It was pointed out that different results were being obtained among the various plants because of the use of different jigs and different machines. It was agreed in committee from the foregoing discussion that a great need exists for the standardization of the method of testing for pin adhesion so that greater use could be made of the test for quality control purposes. It was therefore agreed that a round robin test be conducted by the project chairman in order to determine the best method of performing the pin adhesion test. The chairman, Ked Martin, urged the participation of all committee members and guests in this project and asked for volunteers. The following people volunteered to participate in the round robin test:

Henry Seibel
W. B. Lincoln
H. L. Schlotter
Harvey Stallsmith
Percy Cox
Jim Corcoran
Dean Coder
Henry Ostrowski
Frank Albert
Ned Varner
Henry Nelson
Don Long
Leonard Timmer
George Lecky
Hugh B. Johnson
Alan Schwartz
Harry Dunholter

Harvey Stallsmith, chairman of Project No. 752, entitled "A Survey of Plant Quality Control Methods," was asked to report on his committee progress. Mr. Stallsmith reported that a questionnaire was sent out in July to all committee members. A discussion centered about the wording of certain questions in order to obtain clear, concise answers. Changes in wording were made in several questions after committee agreement. Rewording of section II of the questionnaire was accepted by the committee for better clarification. It was recommended that two separate sections for the questionnaire be used in order to clarify the results for single plants and multiple plants wherein quality is controlled by a central laboratory. The committee agreed to add the following questions to those already listed in the questionnaire:

"How many people are involved in quality control in the plant?"
"What influence does raw materials have on quality control?"

The term raw material refers to all classes of raw materials, such as starches, papers, waxes, etc.

The central theme of this project centers around the question "what is the role of the quality control men in the box plant?" The chairman outlined the over-all objectives of quality control people in improving the over-all quality of the industry. He stated that the setting of standards should be realistic and still do what the customer requires to meet his objectives functionally and appearance wise.

Henry Nelson, chairman of Project No. 754, entitled "Manual of Simple Statistical Techniques," reported that the scope of the project requires a lot of additional help to bring it to completion. He stated that he will list all points which he thinks will be of interest statistically, then obtain agreement on certain points which will be expanded and be made of real value to the industry. He will endeavor to make it simple so a large number of people can use the information, not necessarily technical personnel only.

Mr. Nelson asked for additional people to help him with the program. The chairman pointed out the need for this type of project and suggested at least six people volunteer to help on the committee. The following people volunteered:

Dean Coder
W. B. Lincoln (may be available)
Larry Shipman
D. Wolvin

Harry Dunholter, chairman of Project No. 762, entitled "Defect and Remedy Manual," reported that a glossary of terms for the corrugator, presses, stitchers, tapers, and glue-lap machines has been prepared by the committee and is ready for approval by the entire committtee membership. A copy was distributed to each member of the committee and each guest. Mr. Dunholter pointed out the next step in the project after agreement on terms or definitions will be a listing of the remedies for each defect defined. This will be broken down into several categories and a committee will be assigned the responsibility for each category.

The following people have volunteered their services on this committee:

Kedrick Martin
Ned Varner
Henry Seibel
Alan Schwartz
George Lecky
Stanley Goodrich
Jim Corcoran

Also, Charles Zusi volunteered to assist the committee.

Henry Seibel stated that Project No. 763, entitled "Laboratory Equipment for a Quality Control Laboratory," has been completed. There have been several requests for a report on this project by people in the industry.

The chairman, Ked Martin, called for a new project to be started. He appointed Alan Schwartz to work with two other people on the committee to report on the title of a new project at the next meeting.

The Toronto meeting to be held in the fall of 1960 will be the committee's responsibility. Henry Ostrowski will be the moderator. The theme will be "New Developments in Packaging."

After a lively discussion on the meaning of the word "packaging," it was divided into four categories namely, (1) fragile articles, (2) bulk packaging, (3) displays, and (4) frozen food packaging. There will be a talk on each category covering testing, design, etc. The chairman asked for suggestions for speakers for each of the above divisions of packaging. Two tentative names were suggested:

Ed Polince
Guy Clark

Henry Ostrowski was asked to write to members of the committee asking for suggestions for speakers.

Ned Varner announced the following nominations for officers for the coming year.

Henry Seibel, *chairman*
Harry Dunholter, *vice-chairman*
Stanley Goodrich, *secretary*

Nominations were opened from the floor by the chairman. There were no new nominations. George Lecky moved that the nominations be closed. The move was seconded and the above officers were thereby elected unanimously. The new officers will take office immediately following this meeting.

The meeting was adjourned at approximately 5 p.m.

HARRY E. DUNHOLTER, *Secretary*

REPORTS AND DISCUSSIONS

Presented at National and Regional Conferences

Equipment for Testing Components of Corrugating Media

THE members of the Process and Quality Control Committee have prepared the following list of equipment available for the testing of component material (liner stock and corrugating media), adhesives, inks, printing plates, tape, twine, finished combined board, and boxes. These are grouped as:

1. Basic or "essential" to every laboratory operation.
2. Additional equipment classed as "desirable" for laboratory evaluation.
3. "Ultimate" in the most up-to-date laboratory.

These suggested classifications may vary with some laboratories because of special considerations. However, they can be used as a reference or a guide to check existing quality control laboratories or in the planning of new ones.

As much as possible, reference to manufacturers or specific equipment was avoided. Our TAPPI procedures were listed where applicable.

OBSERVATIONS

1. Many pieces of testing equipment and testing procedures now used in laboratories are not covered by approved TAPPI procedures. Much work is needed in this area in order to complete TAPPI coverage.

2. When considering the overall picture, relatively few new testing equipment and techniques have been added during the last five years.

3. Instrumentation and calibration need improvement.

4. Quality control engineers have generally not included in their testing program: inks, adhesives, tape, twine, printing dies, and other corrugated box plant raw materials.

Even though this list was compiled with the greatest possible care, there may be some missing. Suggested additions should be forwarded to the chairman of the Process and Quality Control Committee.

KEDWICK R. MARTIN, *Chairman*

Recommended Equipment Required to Evaluate Component and End Product Quality in Corrugated Container Manufacture

I. COMPONENT MATERIALS

A. Liners and Corrugating Media

Essential

1.	Mullen or Cady tester for bursting strength measurements.	T 403 m-53
2.	Dial micrometer for caliper measurements.	T 411 m-44
3.	Basis weight, scale or balance.	T 410 m-45
4.	Balance and oven or moisture meter for moisture content determinations.	T 412 m-53

Desirable

1.	Concora medium tester for predicted flat crush strength of corrugating medium.	None
2.	Ring crush or Concora liner tester attachments for MD and CMD Compression Strength of liners.	T 472 m-51
3.	Stiffness tester.	T 451 m-45
4.	Beach puncture tester for determining puncture resistance.	None
5.	Tear tester for determining tear resistance.	T 414 m-49
6.	Densometer vanceometer or smoothness tester for indicating liner printability.	T 479 sm-48
7.	Water tank and balance for measuring water absorption.	T 441 m-45
8.	Pipet or penescope for measuring water penetration.	T 432 m-44
9.	Cobb sine tester for determining degree of sizing.	T 441 m-45
10.	Scuff, abrasion, or rub tester for determining scuff resistance of liners.	T 476 m-51
11.	Tensile tester for determining tensile strength.	T 404 m-50
12.	Inclined plane or friction tester for measuring coefficient of friction.	None

Ultimate

1.	Reflection Meter for Brightness.	T 452 m-48
2.	Color determinations.	T 442 m-47
3.	Vapometer cups and balance for moisture vapor transmission determinations.	T 448 m-49
4.	pH meter for pH determinations.	T 435 m-52
5.	Internal bond tester or wax pick test kit for determining ply bond strength.	T 459 m-48
6.	Fold endurance tester.	T 432 m-50
7.	Light source or formation tester for evaluating paper formation.	None

B. Adhesives

Essential

1.	Scale, hydrometer or densometer for determining specific gravity.	None
2.	Viscosity tube or viscosimeter for determining adhesive viscosity.	None
3.	Thermometer for determining gel point and temperature.	None

Desirable

1.	pH meter for measuring pH.	None
2.	Method of checking for foreign materials—screen.	None
3.	Water tank and sample rack for determining waterproofness of adhesive.	None
4.	Oven and balance for determining moisture content and solids.	None
5.	Stop Watch for evaluating tack and setting time.	None

Ultimate

None

C. Inks

Essential

None

Desirable

1.	Reflection meter for determining brightness, gloss, and color of inks.	None
2.	Tub tester for measuring rub resistance.	None
3.	Clock or gardner recorder for measuring drying time	None

Ultimate

1.	Fadometer or weatherometer for determining fadeproofness.	None
2.	Tackometer or inkometer for determining tack.	None
3.	Scale, hydrometer or densometer for determining specific gravity.	None
4.	Drawdown blade and plate or grindometer for measuring pigment grind.	None
5.	Method of measuring aging.	None

D. Printing Plates

Essential

1.	Durometer for measuring hardness of dies.	None
2.	Dial micrometer for measuring thickness of dies.	None

Desirable
None
Ultimate
None

E. Tape and Twine

Essential
None
Desirable

1.	Elmendorf tear tester for measuring tear resistance.	None
2.	Tensile tester for measuring tensile strength.	None
3.	Gummed tape tester for measuring adhesion.	None
4.	Balance for measuring weights.	None
5.	Dial micrometer for determining caliper.	None
6.	Abrasion, rub, or scuff tester for measuring scuff resistance.	None

Ultimate

1.	Stiffness tester for determining stiffness.	None

II. End Product

A. Finished Board and Boxes

Essential

1.	Mullen or Cady Tester for Determining bursting strength.	None
2.	Dial micrometer for determining caliper.	None
3.	Beach puncture tester for measuring puncture resistance.	T 803 m-50
4.	Basis weight scale or balance.	None
5.	Small compression tester for flat crush resistance.	None
6.	Water-tank and sample rack for testing for wet ply separation.	None
7.	Large compression tester and sealing equipment for determining compression resistance of finished boxes.	T 804 m-45
8.	Steel measuring tape or box gage for measuring box dimensions.	None
9.	Manufacturer's joint tester, drop tensile tester for testing manufacturer's joint.	None
10.	Water tank, iodine solution and paint brush for staining separated liners for inspection of glue pattern.	None
11.	Procedure for inspecting board for flute formation, washboard, warp, scoring, etc. These can be evaluated by visual inspection.	None

Desirable

1.	Oven and balance or moisture meter for determining moisture content.	None
2.	Tear tester for determining tear resistance.	None
3.	Abrasion, rub, or scuff tester for determining scuff resistance.	None
4.	Pin adhesion attachment for small compression tester for measuring adhesive bond.	None
5.	Reflection meter for measuring brightness.	None
6.	Attachment for compression tester for measuring column compression strength.	None
7.	Tester for determining fold endurance.	None
8.	Special compression or tensile tester attachment for determining handhold strength.	None
9.	Vibration tester, comber tester, drop tester, and drum tester for determining box performance in resistance to rough handling.	T 800 m-50 T 801 sm-44 T 802 m-44

Ultimate

1.	Reflection meter for determining color.	None
2.	Film thickness gage for measuring ink film thickness.	None
3.	Compression or tensile tester attachment for determining beam strength.	None
4.	Inclined plane or friction tester for determining the coefficient of friction.	None

III. Calibration of Equipment

Essential

1.	Deadweight gage tester for calibrating bursting strength tester gages.	None
2.	Proving rings, compression gage, or calibration weights for calibrating compression and tensile testers.	None
3.	Feeler gages, pyrometer, ammeter, voltmeter, etc., for calibration and maintenance of equipment in laboratory and plant.	None

Desirable
None
Ultimate
None

IV. Miscellaneous

Essential

1.	Paper cutter and fiberboard knives for sample preparation.	
2.	Laboratory glassware.	
3.	Lubricants for testing equipment.	
4.	Controlled humidity room or chamber for conditioning samples.	T 402 m-49

RECENT BOOKS

Hot Organic Coatings. By Raymond B. Seymour. Reinhold Publishing Corp., New York, 1959. Cloth, $6^1/_4 \times 9^1/_4$, 233 pages. $7.50.

The fundamentals of hot organic coatings are presented by an author with 25 years experience in the plastics and coatings industry. Written not only for the plastics industry, the book should prove helpful to anyone seeking information on hot applied coatings.

Formulations are given and properties and applications are discussed of synthetic as well as natural, widely used hot organic coatings. Chapters have been included on coatings of tar, petroleum and animal waxes, cellulose derivatives, and synthetic hydrocarbon resins. Coatings for specialized applications, (melt spinning and melt casting of clear films, moistureproofing paper, cloth, cellophane, and artificial flowers or textiles) are classified according to their composition: esters, amides, ethers, vinyls, sulphides, epoxy, and phenolic resins.

Chapters have also been included on hot applications with and without solvents, and on standard tests for applied coatings.

Silicones. By R. N. Meals and F. M. Lewis. Reinhold Publishing Corp., New York, 1959. Cloth, $5^1/_4 \times 7^1/_2$, 267 pages. $5.95.

The eleventh book of the Reinhold Plastics Application Series, this volume presents the technology of silicones in semitechnical language.

Although most of the book is devoted to describing the general properties, manufacture, and application of silicones, a brief chapter has been included outlining, in simplified form, the basic chemistry of these substances.

Asbestos. By D. V. Rosato. Reinhold Publishing Corp., New York, 1959. Cloth, $5^1/_4 \times 7^1/_2$, 214 pages. $5.75.

The uses and applications of this remarkable inorganic fibrous material are the subject of this broadly informative work. The author has succeeded in presenting to the various branches of industry a guide, written in simple and everyday language, asbestos products for building materials, cements, adhesives, plastics, paper, textiles, medicine, etc. Readers interested in the more fundamental aspects of research in asbestos will find a useful bibliography to guide them in their quest.

Industrial Fatty Acids. Edited by E. Scott Pattison. Reinhold Publishing Corp., New York, 1959. Cloth, $6^1/_4 \times 9^1/_4$, 230 pages. $7.00.

The Methods of producing fatty acids are reviewed and their general chemical reactions and industrial applications described. Once used only in the candlemaking and soapmaking industries, fatty acids now have a multitude of uses, and the book discusses their application in protective coatings, metallic soaps and greases, cosmetics, rubber technology, surface-active agents, plasticizers, and polymers. A chapter on methods for the analysis of commercial fatty acids has also been included.

Continuous Analysis of Chemical Process Systems. By Sidney Siggia. John Wiley & Sons, Inc., New York, 1959. Cloth, 6 × 9, 381 pages. $8.50.

The control laboratory has always been the "seeing eye" of an industrial chemical process. A titration, a density, or a viscosity measurement made at regular intervals was often sufficient to indicate whether a process was proceeding satisfactorily. Such methods are still in use, but, where once it was necessary to collect a sample, bring it to the laboratory and await its analysis, now, some of these steps can be bypassed. Probes in almost all phases of a chemical process, continuously sample, test, and flash the results back to a central panel without the intervention of a human agency.

The book is an edited compilation of trade literature and bulletins on analytical instruments for continuous analysis and presumes a knowledge of the principles of instrumental analysis and the standard laboratory instruments. The principle, scope, and specifications of every instrument available for measuring a certain value (pH, viscosity, density, refractive index, etc.) is discussed, but no comparison is made between instruments of different manufacture.

The practicing analyst and engineer will find in one place the information which will enable him to select among the various available instruments that which will suit his purpose best. As a companion to a college textbook on analysis, this book demonstrates how a basic principle finds full expression in a practical application.

Books reviewed may be procured through TAPPI, 360 Lexington Ave., New York 17, N. Y.

EMPLOYMENT SERVICE

Positions Wanted

E482-59. Chemist experienced in development and production of paper specialties, is available to assist management in this field.

E483-59. "Expert in cellulose, pulp, wood chemistry, doctor of organic chemistry (Vienna), years of independent work in research, development, production. Austrian lady wants corresponding position.

E484-59. B.S. in Paper Engineering from Lowell Tech, M.B.A. from Wharton Graduate School, U. of Pa., Industrial Management major. Married, one child. Desires position with any size company. Prefers production, but will consider other areas which have prospects for growth and advancement. Experience in chemical and market research, and quality control. Eastern or midwestern location preferred. Résumés and references on request.

Positions Open

P906-59. Excellent future for man in 35 to 45 age group with a leading fine paper mill. Should have a degree in paper technology or chemical engineering, technical and operation experience, and be capable of taking over as production manager.

The National TAPPI Staff is seeking a young man interested in working with the Association's technical divisions. Several years of industrial experience preferred. Broad interest in many branches of the industry important. Applicants please send complete résumé of education and experience to

P. E. Nethercut,
Secretary-Treasurer, TAPPI,
360 Lexington Avenue,
New York 17, N. Y.

(P918-59)

ARMOUR ALLIANCE INDUSTRIES

A Division of Armour & Company

Chemical Engineer—Paper Coating Experience. Our Product Development group requires a qualified person to supervise an extensive pilot plant program on Coated Abrasives.

A graduate Chemical Engineer aged 25–30 years would be preferred.

For further details please write:

Charles L. Dunlop, Personnel Mgr.
Armour Alliance Industries
Alliance, Ohio

(P921-59)

PROCESS DEVELOPMENT SUPERVISOR

Recent promotions in our Technical Department have left an opening for a Process Development Supervisor. This work involves both pulp and paper and all applicants should have an appropriate technical education with five years experience. This is a good opportunity to gain supervisory experience along with professional growth with a progressive company. Salary commensurate with experience and ability. Write to

Personnel Department
Riegel Paper Corp.
Carolina Division
Acme, N. C.

(P922-59)

Technical Sales

Man presently employed as Sulphite Superintendent, Mill Superintendent or similar capacity to represent one of America's largest chemical manufacturers.

Would consider man 60–63 years of age about to retire from present post. Position requires ability to communicate with & interest mill management in a particular cooking base. Will involve limited travel-working from home.

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P923, Tappi, 360 Lexington Ave., New York 17, N. Y.

SALES ENGINEER

Prefer mechanical engineering graduate with paper mill experience, under age 35. This is an excellent opportunity with a progressive manufacturer of paper making machinery. Midwest location. Reply to P928-59, Tappi, 360 Lexington Ave., New York 17, N. Y.

PRODUCTION MANAGER
TECHNICAL DIRECTOR

and other senior staff

required by

a well designed and located, first class, versatile, one machine

FINE PAPER MILL

now under construction at New Westminster, British Columbia

If you would like to be a part of this operation right from the start, and grow with it, you are invited to write now in strictest confidence and fullest detail to the:

Fine Paper Division
Powell River Company Limited
Standard Building
Vancouver 13, British Columbia

(P924-59)

ENGINEERS

Mechanical—Industrial—Chemical

Recent promotions in our organization have resulted in openings for Engineers. We prefer two to four years experience in our own or allied industries but experience in other fields will definitely be considered. Due to our continued expansion, we feel that there is full opportunity for professional growth for anyone joining our Technical and Engineering Departments. Our plant is located in Southeastern North Carolina near several beaches and other recreational facilities. Salary commensurate with experience and ability. Write to

Personnel Department, Riegel Paper Corp., Carolina Division, Acme, N. C.

(P929-59)

DESIGN PROJECT ENGINEERS

Outstanding opportunity for qualified Mechanical Engineers to have complete responsibility for major projects involving the design and development of equipment for the Pulp & Paper Industry.

Excellent facilities provided in new research building including fully equipped pilot plant and laboratory.

PULP AND PAPER RESEARCH CENTRE, INC.
G. H. de Reus, Chief Engineer
P. O. Box 780, Lawrence, Mass.

(P930-59)

PROCESS ENGINEER

Consolidated Water Power & Paper Company is considering applications for the position of Process Engineer.

Our Process Engineers are part of the mill technical staff and operate as an integral part of production on problems involving quality control, wastes and efficiencies. These Engineers are assigned to specific areas in the mill such as Groundwood Pulping, Stock Blending, Papermaking and Coating, and are expected to provide guidance and technical advice to the operating personnel.

This Process Engineer should have an educational background in Paper Technology, Chemistry, or Chemical Engineering.

Two or three years experience in Process Engineering or mill technical service work in Groundwood Pulping, Chemical Pulping, and/or wet-end machine trials is necessary.

This position is located in Central Wisconsin.

Please send resumé and application for interview to **L. J. Barrette, Director of Personnel & Labor Relations, Consolidated Water Power & Paper Company, Wisconsin Rapids, Wisconsin.**

PROCESS DEVELOPMENT SUPERVISOR

Recent promotions in our Technical Department have left an opening for a Process Development Supervisor. This work involves both pulp and paper and all applicants should have an appropriate technical education with five years experience. This is a good opportunity to gain supervisory experience along with professional growth with a progressive company. Salary commensurate with experience and ability. Write to

Personnel Department, Riegel Paper Corp., Carolina Division, Acme, N. C.

(P932-59)

OPPORTUNITIES

With the Research and Development Department of a leading producer of insulating, structural, and decorative fiber products—both flexible and rigid; location in North Central U.S.

Positions Offered:

Chemical Engineer—Work relates to process engineering associated with the development of new products—particularly insulating and rigid fiber boards. As such it involves liaison between Production and Research, and includes variable studies, process design and development, and plant scale demonstration. Applicants should have demonstrated leadership ability and have qualities of initiative, thoroughness and interest and ability to move into new fields. At least five years experience in a board plant or paper mill required, directly relating to pulp or fiber preparation or the paper- or board-felting processes. Graduate chemical engineer preferred but mechanical engineer may be suitable.

Junior Mechanical Engineer—Work relates to the mechanical engineering activities associated with the design and operation of pilot plants and production scale prove-out trials for new felted fibrous products. Applicants should have interest in all aspects of product development from idea stage through commercial production. Process-minded mechanical engineer or mechanically inclined chemical engineer with 0–2 years experience preferred.

Product Development Trainee—Work relates to the analysis, development, and field trial evaluation of new products designed for present and new applications in the building construction field and industrial markets. Applicants must have interest and aptitude in all phases of product development from idea stage through commercial production. Varied and expanding program will include travel, consumer contacts and liaison with Sales. Applicants must be college graduates with 0–2 years experience. Marketing major preferred but not essential.

All salaries commensurate with education and experience.

All applicants should submit a complete résumé of personal data, educational background, work experience and references to:

Research and Development Department
WOOD CONVERSION COMPANY
Cloquet, Minnesota **(P933-59)**

LOCAL SECTIONS ACTIVITIES

Reports of Meetings, Personnel, and Events

Maine-New Hampshire

The fall meeting of the Maine-New Hampshire Section of TAPPI was held at the Lafayette Hotel, Portland, on October 23–24. About 125 delegates were present for the convention starting with registration on Friday morning.

The technical program on "Stock Cleaning" was directed by the General Chairman, Prof. A. J. Chase, University of Maine, in the absence of C. T. Bockus, technical program chairman.

Professor Chase welcomed all delegates and introduced the first speaker R. V. Prive, Nichols Engineering & Reasearch Corp., whose paper was entitled "Vortrap-Vorjet-Vorvac."

The second paper, "Stock Cleaning Before the Paper Machine," was presented by Carl Perkins, St. Regis Paper Co.

The third paper entitled "Ceramics in Centrifugal Cleaning Equipment" was presented by Dean Kohlhepp, Black Clawson Corp.

The fourth paper, "Centri·Cleaners Hardwood Pulp," was presented by Karl Dornish, S. D. Warren Co.

On Friday evening, a banquet was held in the Mayfair Room. Professor Chase introduced James Field from National TAPPI. Mr. Field congratulated the Section on its progress and offered assistance from TAPPI headquarters. The main speaker was Mr. Henry Fales, vice-president, St. Croix Paper Co. Mr. Fales gave an interesting account of his recent trip to Finland. Dancing followed the banquet.

On Saturday morning a panel discussion was held with Robert Hisey, S. D. Warren Co., as moderator. Members of the panel were the speakers of the technical session. Information was given on the effect of centrifugal cleaners on short versus long fibers, free versus forced vortex, effect of back pressure on cleaning efficiency, etc.

A. J. Chase, University of Maine; H. W. Fales, St. Croix Paper Co.; and J. W. Field, TAPPI

Robert Hisey and Karl Dornish, S. D. Warren Co.; Carl Perkins, St. Regis Paper Co., R. V. Price, Nichols Engineering and Research Corp.; and Dean Kohlhepp, The Black Clawson Co.

Committees and Chairmen:
General Chairman: A. J. Chase, University of Maine
Technical Program Committee: C. T. Bockus, Eastern Corp.; A. J. Chase
Local Arrangements: B. H. Taylor, James A. Taylor & Son; J. F. Wright, National Aniline Div.

The resignation of C. T. Bockus from the executive and technical program committees was announced by Professor Chase. E. N. Poor, Hudson Pulp & Paper Corp., was appointed to the technical program committee and W. F. Wood, National Aniline Div., to the executive committee, to replace Mr. Bockus.

The executive committee announced the spring meeting to be held on June 17–18, 1960, at Mountain View House, Whitefield, N. H. Subject of this program will be "Refining."

E. M. Poor

Finland and Finnish Paper Mills

H. W. Fales

I HAVE just spent 2 weeks in Finland as a guest of the Finnish Paper Mills Assoc., along with

Russ Johnson, Vice-president, engineering, Kimberly Clark Corp.
Tom Price, vice-president, operations, Hammerhill Paper Co.
Pete Heuer, vice-president and general manager, Great Northern Paper Co.
Carl Bendetsen, executive vice-president, Champion Paper & Fibre Co.
Geo. Sheets, Manager, Chillicothe Div., Mead Corp.
Ed Lamb, vice-president, Minn. & Ontario Corp.
Bob March, manager, Coos Bay Pulp Operation—Scott Paper Co.
Ernie Vassiere, Madden Corp., New York City

who are the agents for the Finns in this country.

HENRY FALES, St. Croix Paper Co.

While there, we visited 14 different mills making everything from newsprint to handmade papers. Between visits we were royally entertained by the Finns and got to know them quite well. As background information, I would like to tell you a few facts about Finland and the people who live there.

As you may or may not know, they have fought two wars with Russia. Since the last one, which ended in 1944, they, in 5 years, have resettled approximately 430,000 homeless people from Soviet seized land, delivered to Russia in 8 years war reparations amounting to $570 million, mostly in hard goods. They lost over 17,000 sq. miles of land on which were many of their large industrial plants.

Finland has a population of approximately 4,400,000 people. During the war they had 40,000 men in service, with casualties of over 10%.

Finland is one of the few nations in the western world who has not received a nickel in Marshall Plan aid.

While there, we were told a story about Russo-Finnish relations which seems to typify the Finns.

After the war, when Russia annexed Karelia, the Finns in that area were offered the choice of staying in their homes in Karrel and becoming Russian citizens, or leaving their homes with only the clothes on their back. Of the 430 odd thousand Finns living in Karelia, only 80 people stayed.

Is it any wonder—after associating with them for 2 weeks—we have a great deal of respect for the Finns, their way of life, and their love of democracy.

We visited the Karelia border while at the Kaukopää mill of the Enso-Gutzeit Co. It was not like the border I see every day between Maine and Canada. We drove first of all to a high hill overlooking what is now Russian territory. We could see the smokestacks and building outlines of the Enso Kraft mill—the original Enzo-Gutzeit mill—where many of our hosts had once worked. They had not been back in over 15 years. As we stood and watched the smoke coming from the stacks—tears came to the eyes of many of our Finnish friends.

Next we drove to the neutral zone at the border—nobody could go further without a permit, which was very hard to get. In the distance we could see two watch towers—high on stilts. We were told that the Russian soldiers in these towers were watching us through spyglasses. We had been previously advised not to bring cameras to this area. The Finns said if you do you will get us in trouble.

One of the younger Finns in our party had been to the border several weeks before with Lonnie Nesse's son (Lonnie is with Beloit Iron Works as you probably all know.) As a lark, they had gone a few feet into the neutral zone. On their way back to Kaukopää they were picked up by the Finnish Border Police. They had been seen by the Russian guards who had reported them to the Finnish Border Police. It was several hours before they were released, after questioning.

Now back to papermaking. Finland manufactures approximately 1,500,000 tons of paper and board, of which about 1,000,000 tons is newsprint, and other papers, and approximately 500,000 tons is board.

Forest products represent a large part of Finland's economy and pulp and paper is a very important segment of these forest products. Others are sawmilling, plywood, prefab houses, and joinery industries.

The sales of these various products are handled by so-called associations. The Cellulose Union sells the output of all of their chemical pulp mills; the Finnish Woodpulp Union, all the groundwood pulp; the Finnish Board Mills Assocation their kraft board; the Finnish Paper and Board Converters Association, the foreign sales of converted paper and board; and the Finnish Paper Mills Association all of their paper sales.

I would like to tell you a little bit more about the Paper Mills Association. This association is owned and controlled by the member mills, with the presidents of the various mills acting as directors of the association. The association is divided into three departments: Department 1 handles the export sales of newsprint; Department 2 the export sales of all other types of papers, while Department 3 handles the sales of all papers in the home market. The association pays the individual mill for their paper when it reaches the boat for overseas shipment. The association is allowed a $3^1/_2$ to 5% commission, which goes to pay all of the association operating expenses, as well as the banking costs, sales agents commissions, freight, and other miscellaneous expenses. At the end of the year all profits of the association are divided and sent back to the mills on the basis of tons shipped. The association operates in foreign countries through sales agents. In the United States, the Finnish Paper Mills Association is represented by the Madden Corp, of New York City.

The Finns sell to 80 different countries with their main markets being England, United States, West Germany, and South America. At the present time they are shipping approximately 120,000 tons of newsprint into this country and approximately 25,000 tons of other grades of paper.

Interestingly enough, they sell only approximately 60,000 tons of paper to Russia. Trade between Russia and Finland in paper, as in all other products, is arranged through 5-year trade agreements. Each year, tonnages are fixed for the next year under this agreement.

One of the first unusual things that you notice when you arrive in Finland is the large number of women working in the mills. When we visited the Kotka mill of Enso-Gutzeit Co., we saw men and women working on an equal basis, pushing logs into the jackladder of the sawmill. Also, the sorters in the sawmill were female. We were told that women comprise between 10 and 25% of the total working force in the pulp and paper mills. We were amazed when we looked up and saw the traveling crane operators in the foundries were women.

During our tour of the Kaukopää mill we noticed a Cambio barking operation shut down due to bark piled up under the transfers. Much to our surprise a young lady of about 20, dressed in high boots, was in the middle of this bark pile cleaning it away from the conveyor with a pitchfork, while four of the male workers were leaning against the conveyor watching her. I am sure all of us could profit by this experience. I have tried some of these tactics since returning home, but I must admit the only thing that I have accomplished, is that I seem to be wiping the dishes more than ever.

One of the mill managers, when asked about this high percentage of women working in the factories, indicated that the heavy war casualties among the male population of the country forced many of these women to support their families. Because of this fact it was actually necessary for them to work on these unskilled labor classifications.

We were all impressed with the extreme cleanliness of not only their mills, but the country generally. This may be due to the female influence, since every paper mill we visited had a force of women janitors. Where we have male sweepers on our paper machines, who usually disappear when the sheet breaks down, the female janitor on their paper machine was always in sight. There was not a scrap of paper on the floor, and as Ed Lamb remarked, "What am I going to do with this cigarette butt?" It was just out of place to throw it anywhere on the ground.

Labor rates were considerably lower in Finland than comparable ones on our country. Machine tender rates on high-speed newsprint machines, such as are operated by the St. Croix Paper Co. and the Great Northern Paper Co., was approximately $1.00 per hour, with base labor lower in proportion. These can be compared with our rates at the same machine speed of over $4.00 per hour. We were told that the dollar in Finland would probably buy as much as $2.00 in

this country. However, there is still a considerable difference in real pay.

This lower wage rate was, in our opinion, partially offset by the overstaffing of their mills. A two-machine newsprint mill which would be operated in this country by approximately 350 people, employed over 500 people in Finland. Don't tell this to the Unions—but every machine tender and back tender had a helper. The machine tender's helper was a boy of about 14 or 15 and this was the spot they placed their young people to train as papermakers; from that job they went to sixth hand, and up the ladder to 5th, 4th, 3rd hand, back tender's helper, back tender, and finally machine tender.

The Finns feel they must keep unemployment down or those people who are out of work will become communists. For this reason they employ people, even though they do not need them. They would rather do this than support them through taxation.

The forests in Finland were as clean and well kept as the inside of the paper mills. All trees are harvested by selective cutting practices with only the smaller trees going to the pulp mills. All trees over 5 or 6 in. in diameter are saved for the sawmills. It was interesting to drive through the countryside and see pulpwood, which had been draw shaved to remove the bark, piled in hollow squares for drying.

There was no sign of slash anywhere, since it apparently is removed or burned as soon as the tree is cut down.

Finnish law requires all pulpwood which is to be floated in the water any length of time to be barked beforehand.

At some of the paper mill towns we visited, a number of schools, the Town Hall, and worker housing developments were seen, which are springing up all over Finland. In one town we learned that within the last 10 years, three new schools had been built, a new Town Hall, and approximately 600 worker-owned homes.

Individual taxes are high. Industry pays about the same as it does in the United States. Our information indicated a company pays about 12% of gross profit to the community, 40% to the state, and 1% to the church as taxes. In a town of approximately 14,000, taxes of approximately $1,000,000 were raised each year. The paper company, which was about the only industry in the town, contributed 10 to 12% of these taxes, with the balance being raised through individual taxation. We were told an individual earning $2500 must pay taxes of about $500.00. This is somewhat different from our system.

Schools appear to be excellent, at least in physical appearance, and from the apparent technical excellence of the Finnish engineers, the educational system must be as good as the physical properties of their school buildings. In Finland it is compulsory for each child to go to school for 7 or 8 years. After that the smart ones go on, but the below average child must go to work and is put into the worker status for the rest of his life, without much hope for further advancement. The above average student goes on to high school and then, if able, to the technical universities. In Finland the engineer seems to have a higher social status than any other professional man, such as the doctor and lawyer.

In the paper and pulp mills, all department superintendents were technically trained university graduates. The practical man would not be allowed to head a major phase of their business.

At one mill we visited a company trade school in which 84 boys of ages 16 to 18 were studying. These boys were at this particular school for 3 years, working in the mill during the summer months. Most of them were sons of employees of the various mills. They were being taught machine shop practices, electricity, and paper and pulpmaking. Upon graduation they went to work in the mills full time. After one year's compulsory army service and about 3 years as a worker, they were promoted to foremen positions. In this way each company seems to train their own supervisors.

As I mentioned earlier, house building was progressing at a tremendous rate, with as they call it "The Own Home Program" very much in evidence. An employee could secure a $3000 loan from the company, another loan of $4000 from the State, with the balance of the cost being contributed in labor by the owner and his neighbors. Houses seem to cost about $10,000 and to be in the price range of ours. We visited some of them and found them extremely well kept. The Finns love flowers and their gardens and yards reflected this and were really beautiful.

The church is State owned, with at least 95% of the Finns belonging to the Lutheran Church. Apparently in some of the Scandinavian countries the minister of the Lutheran Church actually works for and is paid by the State.

Technically I do not think we saw any startling developments. As I mentioned earlier their technical people are extremely well trained and very competent. It was my feeling that age for age the Finnish engineer was further advanced than the majority of our young engineers. The Finn seems to be better trained when he leaves their universities and is able to take over responsibility faster than the average graduates of our universities when they enter our industry.

In newsprint they are operating paper machines, most of them manufactured by Beloit in the last few years, as well as we are operating ours. In many cases they are holding the speed down, due to the depressed market conditions.

They are very quality conscious. They recognize they have only one thing to sell and that is quality. This makes them extremely good competition and I am sure we are going to hear more of them as the years go by.

We saw at least five new high-speed newsprint machines being installed and since returning to the States I have read of two more being ordered. In addition, we also saw several kraft board and sack paper machines being erected. They also are being built by the Beloit Iron Works.

Because of the high price of coal the Finns have made every effort to save B.t.u's. We saw many sulphite spent liquor recovery boilers on calcium base. One mill operator informed us that he had saved over 50,000 tons of coal last year from his calcium recovery boiler operation.

Another interesting development was the Sulzer vacuum pump. This centrifugal compressor is generally used throughout Finland as the vacuum pumps on the paper machines. We were all very enthusiastic about this. We saw a number of high-speed wide newsprint and kraft paper machines with their vacuum requirement being supplied by one of these pumps using a 750 h.p. motor. A number of us agreed the next time we found it necessary to install a vacuum pump the Sulzer was certainly worth a trial.

Anybody who visits Finland and talks about it must, before he finishes, tell of the Finnish bath or as it is known there —the Sauna. Basically it is something like the New England clam bake, with the individual being the clam. These Saunas usually are in a separate building, preferably by the lake shore. The best ones are built of logs, have three separate rooms —one room being the sitting room, in which are couches, chairs, and a table covered with bottles of beer, vichy water, and other soft drinks. Immediately next to this room is a small anteroom in which are half hogsheads of cold and hot water.

When you reach the Sauna your Finnish hosts tell you to undress, after which you go into the anteroom and pick up a pail of hot and cold water. Then comes the Sauna. When you enter the third room, you see a small stove in the corner. This stove has a fire in it with a number of large rocks on the top of the stove over the fire. The heat almost knocks you down. We found out afterwards there were hot Saunas and cold Saunas. When you want a cold Sauna, which might be 185°F., you put a little water on the hot stones. This causes the room to be filled with steam, and believe it or not cools it off. The Sauna has

several benches in tiers, with the top bench close to the ceiling. We sat on the top bench. The bucket of cold water is used to sprinkle on the bench to cool it off before you can sit down. We all sat on the top bench for about 10 minutes and believe it or not the temperature was 230°F. While sitting there and meditating in the heat, our hosts showed us how to dip birch boughs in the bucket of cold water and switch our bodies with them. This apparently kept our circulation up to par.

After taking this for a while our host said "Now we must jump in the lake." We all went out and dove in the lake which was 52°F. Back to the Sauna we went, sat for 10 more minutes, until the perspiration was really running, and then back to the lake and believe me it had not warmed up a degree. Then we all went back to the living room and relaxed over a bottle of beer. Somebody said "That treatment is as good as a cardiograph." However, I am told that nobody ever died in the Sauna. Probably they died when they jumped in the lake.

Presented at the Maine-New Hampshire Section of TAPPI, Portland, Oct. 23–24, 1959.

Vortrap—Vorject—Vorvac

R. V. Prive

VORTRAP

THE first liquid cyclone classifier commercially applied to cleaning pulp stock was the Nichols Freeman Vortrap. This device was developed by Consolidated Paper Corp. Ltd., under the direction of Horace Freeman and placed on the U. S. market in 1936 by Nichols Engineering and Research Corp. Since that time, the Vortrap has been in continuous service and successfully applied for the removal of sand, grit, and foreign material from all types of pulp and papermaking stock. There are nearly 5000 units in operation throughout the United States with a capacity of 225 g.p.m. or more per unit, and this is strong proof of the popularity of the Vortrap and its contribution to the paper industry.

Several papers have been presented on the Vortrap, but occasionally there is some confusion on the differences between this cleaner and the Vorvac and Vorject more recently developed, and the specific function each is designed to perform. This paper will deal with all three cleaners and endeavor to clarify the construction and application of each type.

The Nichols Freeman Vortrop is available in six sizes.

$1^1/_2$ in. with a rated capacity of 25 g.p.m.
3 in. with a capacity of 125 g.p.m.
4 in. with 4 in. cylinders with a capacity of 225 g.p.m.
4 in. with $4^1/_4$ in. cylinders with a capacity of 250 g.p.m.
6 in. with a capacity of 450 g.p.m.
8 in. with a capacity of 800 g.p.m.
10 in. Vortrap which has a rated capacity of 1200 g.p.m.

A recent addition to our line of low pressure drop cleaners is the Nichols pre-cleaner. This unit is designed to operate at pressure drops ranging from 5 to 15 p.s.i. The pre-cleaner is presently available in three sizes:

The 36 in. with a rated capacity of 1500 to 2400 g.p.m.
The 42 in. with a rated capacity of 2400 to 3800 g.p.m.
The 48 in. with a rated capacity of 3800 to 6000 g.p.m.

The Nichols pre-cleaner is presently being tested on several types of paper stock, and preliminary reports are very encouraging. The pre-cleaner may be furnished in either mild steel, or stainless steel construction, and is primarily used to remove the heavier types of foreign material such as nuts, bolts, tile, cement, etc. The unit has also proved to be effective in the removal of sand and other fine, dense material.

The installation of this equipment may be considered ahead of screens or high pressure drop centrifugal cleaners to protect this equipment.

Vortraps should be operated with a positive outlet pressure; 2 to 3 lb. is adequate, but they can be operated at higher outlet pressures, if required. The $1^1/_2$, 3, and 4 in. Vortraps should be operated at a 22 to 25 lb. pressure drop when operated as a single unit, and a 25 to 30 lb. pressure drop when operated in parallel. The 6 in. Vortrap is operated at a 16 to 18 lb. pressure drop, and the 8 and 10 in. Vortraps are normally operated at a 12 to 14 lb. pressure drop.

All Vortraps are comprised of essentially the same parts: a headpiece, upper cylinder, upper diaphragm, lower cylinder, lower diaphragm, cone, column fittings, and a waste receiver. For the 6, 8, and 10 in. Vortraps, an automatic rejects valve may be substituted for the waste receiver.

Many papers have been given describing the hydraulic action within the Vortrap and, therefore, we shall not repeat it here. It might be in order, however, to describe some of the types of systems and their development.

The Vortrap may be operated as a standard unit, or system, when there is no continuous bleed. In this type of system, dirt removal from the waste receiver is dependent on gravity settling. The dirt displaces an equal volume of water. The water causes a slight countercurrent which holds back the fiber. This type of system is efficient mostly on heavy particles and requires manual dumping of the waste receivers periodically.

Early in the development of the Vortrap and its application, the use of primary-secondary cleaning was developed as a means to improve cleaning and provide continuous operation, without attention from the operator, except for normal routine checking of the system. Later, with larger systems, a tertiary system was added to provide better control and still greater reduction in fiber losses. The Nichols Freeman Vortrap was the first centrifugal cleaner incorporating these features offered to the pulp and paper industry.

In the early stages of the development of the primary-secondary system, the units in the primary system were furnished without waste receivers. An orifice was installed in the column assembly and the rejects collected in a trough, where white water was added to reduce the consistency. These rejects were then taken to the suction of the secondary pump and processed in the secondary system. Later, a rejects header was used in place of the trough, and the rejects taken to a make-up box where white water was added; or the primary rejects were collected in a header and piped directly to the secondary pump suction where white water was added for dilution to effect a "closed system" to prevent infiltration of air at any point. In later years, it was found more practicable to use the standard assembly with waste receiver, adding a small quantity of water under constant pressure at the bottom to control the downward flow of rejects from the Vortrap. The water dilutes the rejects from the Vortrap. The water dilutes the rejects and helps to sluice them through the union tee and $^1/_4$ in. orifice at the top of the waste receiver. In most cases, enclosed piping is used to the secondary pump suction. The same arrangement is used when tertiary stages are added.

The Vortrap system is still in wide use and many mills are very satisfied with the results obtained. To effect efficient Vortrap operation:

1. Operate Vortraps at the recommended pressure drops. This can be done by making certain that gages are installed and working properly.
2. Periodic inspection of the Vortraps. There are many Vortraps which have been in operation 15 to 20 years. Disassembly and inspection is recommended at least once a year. Nichols Engineering, or its representatives, will be glad to assist with information regarding inspection.
3. Add instrumentation to systems which have recirculation.

This insures uniform and constant outlet pressure and

R. V. PRIVE, Nichols Engineering and Research Corp.

volume from the Vortrap system. This involves an air operated valve in the recirculation line, operated by a pressure control instrument. The machine tender operates only the valve to the headbox or process.

There are many applications where Vortraps can be used as a practical and economical answer to your cleaning problems. They require only about one half the horsepower of high pressure drop cleaners and, therefore, effect a substantial saving in power.

VORJECT

The Vorject cleaner was developed at Consolidated Paper Corp., Ltd., by John Boadway under the direction of Horace Freeman and actually was part of Vorvac development. The Nichols Freeman Vorject cleaner is significantly different from the Vortrap and other later makes of centrifugal cleaners. It is designed to operate as a high pressure drop cleaner, and to provide the highest cleaning efficiency on many grades of pulp and paper stock with a minimum of plugging difficulties and low maintenance costs. There are at present three sizes of Vorject cleaners; the standard 610 with a capacity of 480 g.p.m., the 601S with a capacity of 440 g.p.m., and the 306 rated at 100 g.p.m. These are all feed capacity ratings at a 50 lb. pressure drop. The reject rate of the 610 model is 15 to 20 g.p.m., and the 306 reject rate is 5 to 7 g.p.m.

The Vorject is of stainless steel construction, with mild steel flanges and support lugs and usually is equipped with bronze rejects fittings and stainless steel rejects orifice. The rejects fittings may also be furnished in stainless steel if desired.

The Vorject assembly consists of fabricated headpiece, fabricated cylinder, cast cone and either a coretrap, or elutriation assembly, which are cast stainless steel. Units equipped with the coretrap are used as primaries, and units equipped with the elutriator are normally only used as the final units rejecting to waste. This latter assembly may also be used on special applications where only one or two units are required, thus possibly eliminating the necessity for a secondary system.

The stock enters the Vorject through the inlet nozzle which converts a high proportion of the pressure energy into velocity. The suspension is forced under pressure through the tapered tangential inlet into the upper end of the cylinder and spirals downward against the separating chamber or cylinder wall. The accepted stock spirals inward and up through the central vortex to the accepted outlet at the top of the headpiece. Foreign material is thrown out of the stock so that by the time the stock reaches the bottom of the cylinder, the foreign material is next to the wall. There is a slow moving liquid layer next to the wall moving down the cylinder which receives the separated material and acts as a carrying agent as it moved toward the cone at the bottom of the cylinder.

The curved cone, coretrap, and elutriator are the most important features of the Vorject design. The cone acts to turn back the cleaned stock and to allow the slow moving layer of stock with rejects to pass through. The cone is curved so that large particles find no support on the wall and, therefore, are forced downward and out the bottom into the coretrap, or elutriator, as the case may be. Because of the decreasing diameter of the cone, there is an increase in velocity in that area. This concentrates fine, dense particles in the slow moving thin layer next to the wall. At a certain point the wall of the cone becomes almost perpendicular and offers little support to the rejected material, and thus helps carry it out to the reject system.

In the primary type unit, a coretrap is used to discharge the rejects. The coretrap is designed to withdraw the undesirable material from the edge of the vortex while the gaseous core is retained. Air suction is thus prevented. Rejects from the coretrap are taken off through a tangential outlet and the rate of discharge is controlled by means of an orifice located in the rejects fitting. The reject consistency may be from two to four times the inlet consistency, depending on the type of stock.

The secondary type Vorject is identical to the primary except that an elutriation rejects control assembly is used in place of the coretrap. In this device, rejects from the bottom of the curved cone are discharged into the center of a slow moving column of water through which the foreign particles fall. The acceptable fibers are swept back into the body of the cleaner with a small amount of water from the elutriation chamber. The rejected material is bled away from the unit tangentially at a flow rate controlled by an orifice. The fact that the gaseous core is not open to atmosphere with the tangential reject design prevents air insuction. The control water is added to the top of the elutriator, and either fresh or white water may be used. The amount of water added is readily controlled by simple valve adjustment. By controlling the quantity of water added to the elutriation assembly, not only can fiber loss be controlled but, if desired, the size of particles rejected by the unit can be selected.

It has been found that cleaning performance is improved, especially on shive removal, with a rejection rate of 10% or more from the primary cleaners. It is also important to have a relatively high percentage of fiber rejection when the quantity of undesirable particles to be rejected is quite low. It is also true that rejected material may be less than 5% of the feed and still give nearly the same performance.

The Vorject cleaner is capable of doing a very effective job of removing shives, sand, scale, and speck dirt which screens do not remove efficiently. Vorjects can be installed to do a superior cleaning job on all types of pulp and paper furnish. There is a size to fit every application. Vorjects are designed with the idea of supplying to the paper industry equipment which is modern in design, efficient in operation and in which air suction is prevented without the use of vacuum, eductors, or other similar devices. The Vorject operates with almost complete freedom from plugging difficulties, and fiber losses are readily controllable within acceptable ranges. After nearly 4 years of continuous operation on all grades of furnish, the Vorject has proved its dependability and economy by requiring little if any maintenance.

A larger size Vorject will be available shortly for use where units with greater capacity may be advantageous.

VORVAC

Where it is desired to remove both dirt and air from paper machine furnish, the Nichols Freeman Vorvac centrifugal separator can be employed. The Vorvac removes dirt and air simultaneously.

The Nichols Freeman Vorvac separator was developed in the Research Department of Consolidated Paper Corp., Ltd., by Horace Freeman and John Boadway, and introduced to the paper industry at the Canadian Pulp & Paper Association meeting in Montreal, in January, 1953, and at the Technical Association Pulp & Paper Industry in New York, in February, 1953.

The Vorvac design is quite similar to the Vorject with the body of the unit comprising a headpiece, cylinder, and curved cone. The action of centrifugal separation is much the same as in the Vorject. In the Vorvac, liquid is forced through a nozzle type inlet which converts pressure energy into velocity. This nozzle enters tangentially into the Vorvac cylinder, causing the liquid to follow the wall in a helical path. The centrifugal force developed because of the high tangential velocity carries the dirt to the wall where it is swept along to the bottom of the cylinder. The curved cone turns back the cleaned stock, which spirals into a smaller radius and moves upward in a helical path. Because of the high velocity, the liquid is forced by a centrifugal effect to leave a vacuum space in the center. The return, inner upward spiral of stock is thereby subjected to reduced pressure which causes gases to come out of solution, to form bubbles which, along with any

bubbles originally present, are rapidly displaced by centrifugal force to the core.

The headpiece is designed to trap the gas core so that no gas removed from the stock is taken off with the accepted stock. The rejected dirt spirals over the surface of the curved cone and into the separator tank attached to the bottom of the Vorvac. This tank also provides the means for applying a vacuum to the gas core.

A vacuum pump with a line to the top of the separator tank applies a vacuum to the rejects and to the central core in the Vorvac to withdraw the gases and light rejects present near the center of the core. The gases are taken off the top by the vacuum pump and the rejects are taken out the bottom to a secondary Vorject system.

Cleaned, deaerated stock is drawn off the top of the unit by a centrifugal pump which discharges directly to the headbox.

The level in the separator tank is maintained by a level control instrument connected to an air operated valve in the white water make-up line to the secondary pump suction. It is important to keep the level constant so that the vacuum pump is not flooded or air drawn into the secondary pump.

The accepted stock is under vacuum as well as the rejects. A differential controller connected to an air operated valve in the recirculation line maintains a constant differential vacuum between the separator tank and the Vorvac outlet.

The basic principle of a Vorvac system is the same as any conventional stock cleaning system. Briefly, a system would operate as follows:

Stock at headbox consistency is introduced to the suction of Vorvac pump A. This stock is pumped to the inlet header of the Vorvacs at a 10 lb. pressure. Accepted stock from the outlet of the Vorvac system is piped directly to the suction of Vorvac pump B. By means of a valve at the discharge of this pump the vacuum at the outlet of the Vorvacs is adjusted to 15 to 20 in. This outlet vacuum is set at the time of start-up and is dependent upon the vacuum in the separator tank which in turn is affected by the stock temperature. Vorvac pump B discharges directly to the paper machine headbox, with a recirculation line provided to maintain a constant volume of stock through the Vorvacs and to keep the system in balance. A constant Vorvac outlet vacuum is necessary to insure a uniform rejects bleed rate and to maintain the gas core in the center of the Vorvacs. In order to maintain a uniform outlet vacuum from the Vorvacs, a pressure control instrument is used. This valve actuates an air operated valve in the recirculation line and in this way controls the water to the machine. The operation of the manual valve in the line to the headbox by the operator will allow the instrument to automatically control the outlet vacuum by varying the amount recirculated.

The Vorvac is available in two sizes, the 824 which has a rated accepted capacity of 1125 g.p.m., and the 616 which has a rated accepted capacity of 500 g.p.m. By installing units in parallel, any flow requirement can be handled. The largest installation at present consists of twenty 824 Vorvacs with nine secondary and one tertiary 610 Vorjects. This installation is on a newsprint machine currently operating at 2300 to 2400 f.p.m.

The more popular size Vorvac, the 824, has a 24 in. diameter cylinder and requires 20 to 22 ft. of headroom for installation. The unit weighs approximately 2000 lb. and a single unit installation requires a floor space 3 by 4 ft. The Vorvacs are furnished in stainless steel as are the Vorject cleaners.

It is important in designing a Vorvac system that close attention be paid to pump heads. This is particularly important on the secondary pump. The center line of the suction must be at least 10 ft. below the liquid level in the separator tank. Low NPSH conditions exist so the secondary pump must be carefully designed to provide one with proper NPSH characteristics.

The Vorvac system is quoted as a unit and includes:

A. Primary Vorvacs
B. Secondary Vorjects
C. Separator tank
D. Structures
E. Headers
F. Pumps
G. Motors
H. Differential control instrument
I. Level control instrument
J. Air-operated valves
K. Gages

The mill furnishes, unless otherwise specified:

A. Piping
B. Wiring
C. Starters and switches
D. Installation and erection
E. Manually operated valves

It has been proven by tests that it is necessary to remove a substantial amount of air to get full machine benefits. One installation with the temperature of the stock of the headbox 140°F. and 0.3% air had foam in the headbox. It was necessary to reduce the air content to 0.15% to get rid of the foam and obtain machine benefits.

The method used for testing the per cent gas was developed by John Boadway and was described in an article, "Gas in Papermaking Stock." This article appeared in *Pulp And Paper Magazine of Canada*, 1956 convention number. This method tests gases for per cent of volume at 15 in. vacuum.

Tests have been made on various types of stock from Vorvac systems and these tests showed consistently good results:

On glassine stocks air was reduced to	0.1%
Bleached kraft	0.06%
Unbleached kraft	0.03%
Book paper	0.031%
Newsprint	0.1%
Tissue	0.034%

The advantages that can be obtained by the installation of a Vorvac system are numerous:

1. High dirt removal efficiency
2. Eliminates foam in the headbox: eliminates foam killers
3. Eliminates headbox showers: raises headbox temperature
4. Decreases slime spots: reduces number of headbox hosings
5. Increases drainage rate
6. Improves fiber suspension and formation
7. Decreases steam requirements
8. Increases production

Our claim of 5 to 7% increase in production has proved to be conservative. All Vorvac systems are designed to allow for 15% increase. The greatest benefits have been noted on glassine stock and on newsprint stock, perhaps because of the characteristics of these furnishes. Although not all mills will receive the advantages to the same degree because of their different physical machine setup, there is no question that the substantial—not partial—removal of air will condition the stock and overcome many of the problems of machine operation along with many of the other benefits. Any mill having problems with air and dirt in stock at the headbox should investigate the Nichols Freeman Vorvac system.

The Vortrap, Vorject, and Vorvac units are separate and distinctly different pieces of equipment and are the result of about 25 years of experience in the design, construction, and application of centrifugal stock cleaners.

Development to effect improvement in cleaning performance has been under way for many years. Recently, a new size cleaner of great promise has been developed and tests indicate the performance to be superior to any other cleaner now available. It is our expectation that this cleaner will be available to the industry in the very near future.

Presented at the Maine-New Hampshire Section of TAPPI, Portland, Me., Oct. 23–24, 1959.

Stock Cleaning Before the Paper Machine

C. D. Perkins

This paper will describe the stock cleaning systems before the two Bucksport machines trimming 210 to 215 in. each and running at speeds of 12 to 1500 f.p.m. No. 1 machine makes 25 to 45-lb. uncoated book paper while no. 2 makes 40 to 50-lb. machine-coated book paper.

The equipment now in use has been installed within the last 2 years and on both machines all the equipment was put in with no shut-down time except the normal one-down Sunday out of three. This was the result of close cooperation and planning between the suppliers and the mill engineering and operating departments. Where some equipment was to be installed in the same location as that being replaced, it was necessary to have temporary installations of the new equipment while the old was being removed.

Bauer cleaners (originally known as Centri-Cleaners) were installed on both machines replacing older Dirtec units on no. 1 and Vortraps on no. 2 machine. I should like to point out here, the fact that the new cleaning and screening systems are operating more efficiently than the old does not mean they are the only types that would show an improvement. Any new equipment by any manufacturer would show an improvement over an older system made obsolete by overloading and wear. The combination of systems being described is the one that was selected as being best suited to one particular mill's needs and the discussion should not be taken as indicating this to be the only practical combination.

On both machines, Black Clawson Miami Selectifiers replaced older Bird Screens, while a Jonsson flat screen replaced an old Impco flat screen.

Since there is no pulp mill cleaning except the ordinary sulphite flat screens and groundwood rotary screens, it is doubly important that there be efficient cleaning at the paper machines. Since it is economically impractical to get much peeled wood, the woodroom with rotary washing drums now used for barking cannot provide 100% clean wood, another reason for having good cleaning at the machines. The reasons that make it necessary to have clean paper and the degrees of cleanliness required are as varied as the number of grades produced. Two extremes might be car liner and waxing paper base. In car liner, made largely from screenings, anything which will pass through the machine presses is allowed, while for waxpaper the sheet must be both physically and chemically clean. It looks now with some of the proposed FDA rulings as though producers of paper, other than food wrap, will be more closely watched on the matter of sheet additives, but for our mill and most others in the state the obvious reason for a clean sheet is appearance. Here again, there is a range of cleanliness, from unbleached newsprint to the high-grade bond paper which may be sorted sheet by sheet to eliminate paper containing dirt specks. Somewhere between these are the printing grades such as made at Bucksport. Along with the primary reason of sheet appearance there are other reasons for having good cleaning systems. One of these is prevention of damage to printing press cylinders. Since the printing plates are soft they are easily damaged by grit such as might come from coarse clay, grinder stones, or digester linings. Another reason for eliminating grit is better operation on the paper machines and supercalenders in the mill itself. A mill on the West Coast, as reported in *Tappi*, found the following improvements after installing a new cleaning system:

A. Increased wire life by 25%.
B. Reduced changes of calender rolls from every 4 to every 10 months.
C. Reduced changes of king roll doctor blade from every 2 weeks to every 6 months.
D. Reduced dulling of slitters and rotary cutters.

The customer, however, is the one who must be satisfied and in the case of most of our grades, the final customer is the advertiser who has purchased expensive ads in magazines such as *Life*. They do not, of course, want to see a blotch on the nose of some girl in a cosmetic ad or a scratch on a new washing machine.

Since the start-up of the new cleaners and screens there have been no complaints or criticism on dirt from any of the mills' customers. In fact, there have been several favorable reports from customers on sheet cleanliness. The matter of stock cleaning is a good sample of what is a very familiar phrase to those of us who had contact with Professor Jenness at the University of Maine—"Economic Balance." It is necessary to know the requirements of the customer and then meet the requirements in the most economical way. From the woodroom to the paper machines there are two basic costs to be considered. First the equipment, labor, and power required to do the cleaning, and second the cost of the material being rejected. Despite the use of secondary and tertiary screens and cleaners there is always some good material being rejected. For efficient operation this must be kept at a minimum.

On each machine at Bucksport the stocks and broke are proportioned through a new Trimbey metering system to a jordan supply chest, pumped to a weight regulator, and passed through jordans to the fan pump. The stock is diluted to 0.6 to 1.0% with wire pit water and is pumped through the primary system of 229, 623, and 500 g.p.m. Bauer cleaners. The accepted stock goes to the Selectifiers while the rejects go to three secondary units like the primaries. The rejects from the secondaries go to the tertiary system of two, no. 606-90 g.p.m. units. The rejects from the tertiary unit are sewered, with normal fiber losses being from 0.25 to 0.40% of the fiber being furnished.

With the installation of the Bauer cleaners there was a 50% reduction in dirt count on the paper and along with it a decrease in the amount of stock being sewered. So although the sheet became cleaner, the amount of stock being sewered dropped, indicating a more selective cleaning action.

Several types of centrifugal cleaners have been developed since the time when all separation of heavy particles was done in rifflers. Since these depended entirely on gravity for separation, only particles with great differences in specific gravity could be settled out. Rifflers also used a lot of space and that was a drawback with machines speedups. Centrifugal cleaners were developed to increase the force acting on the particles. They allowed the settling of particles having specific gravity only slightly greater than the good fibers and also had a smaller space requirement.

The development of the Bauer cleaners was the result of cooperative research by the Hammermill Co., Howard Smith Ltd., and the Bauer Bros. Co. Without going into the theory of operation, the basic difference was the conical design of the Bauer cleaners to pull a free vortex rather than a forced vortex such as on the conventional types. A free vortex is open at the bottom and the fluid velocity accelerates in the open conical section. With the increase in tangential velocity and the decrease in cone diameter there is an increase in revolutions per minute and, consequently, an increase in force on the particles.

For example, if the radius is 6 in. and the tangential velocity 20 ft. per sec., a reduction in radius to 2 in. increases the tangential velocity to 60 ft. per sec. The increase in revolutions per minute is from 382 to 3440. This gives a centrifugal force of 710 times the force of gravity working on the particles at the 2 in. section of the vortex. This force allows good separation of particles with the accepted stock rising to the top and the rejects being eliminated at the bottom.

Bauer cleaners have two methods of air removal at the base of the cone, eductor nozzles and vacuum pump. To get a good comparison, one system of each type was installed at

C. D. Perkins, St. Regis Paper Co.

Bucksport. The vacuum pump system gave the best operation and the unit with the eductor system was converted to vacuum pump. In the eductor system the vacuum is pulled by water at 40 lb. pressure going through eductor nozzles at the base of each core. This is generally paper machine white water pumped from a storage chest and quite often contains pebbles or pieces of concrete. These of course plug the eductor nozzles making it necessary to isolate the cleaner and remove the plug. Not only is this time consuming, but it also throws the machine system out of balance when a cleaner is shut down. With the eductor system there was wearing of the eductor nozzles so eventually more white water than necessary was getting into the reject system and overflowing the reject pump box.

The vacuum system is easier to maintain, with a vacuum pump and receiver replacing the white water pump and eductor nozzles.

One of the main features of the vacuum system is that fiber losses have remained constant over a one year period while on the unit with the eductor system there was a 40% increase in losses in a year. When it was changed to vacuum system the rejects dropped to the start-up rate and the sheet became cleaner. The reason for the increase in losses appears to be due to the increased size of the underflow nozzles due to abrasion. The 23-in. vacuum of the vacuum system seems to pull the rejects down in a straight flow while with the eductor system there was quite a lot of swirling in the reject nozzles. The air removal by the vacuum system has helped to make a better sheet and on some sheets it has been possible to make a cut in defoamer usage, but on some others it has not.

The primary and secondary units operate at a 50 lb. pressure drop while the tertiary unit has a 40 lb. drop from the inlet to the accepted stock outlet. The cleaners are quite trouble-free, with the biggest initial problem being wearing of the rejection nozzles. Because of the large amount of clay in the stock, along with grinder grit, there is a lot of abrasive action and it was necessary to replace the rubber disk nozzles originally supplied, with nozzles of Stellite no. 90, a high chrome iron alloy.

The fan pumps to the primary units deliver 12,500 g.p.m. against a 200-in. head. The accepted stock from the Bauer cleaners goes to headers and then to five Selectifiers for each machine. The flow in the Selectifiers is downward and out through the 0.062 in. perforations in the screen cylinder. The screen cylinders are vertical, 2 ft. by 2 ft. and stationary. The inside of the cylinder is kept clear by a pair of rotating bars revolving at 300 r.p.m. The type we have are non-contacting air foil bars in which there is a clearance of 0.030 in. between the bars and screens. By having no metal to metal contact there is less wear than on the older types in which the blades act as scrapers. The air foil bars create a slight vacuum as they rotate and pull back fibers which may have plugged the screen.

Rejects are continually removed through a 4-in. wide volute trough. At the bottom a 4-in. line leads to a heavy trash box. A valve can be closed before this box and the trash box is dumped every 8 hr. Lighter rejects flow past the trash box and are discharged to the flat screen.

Since the original installation of the Selectifiers it has been necessary to change from grease to water seals at the base of the rotors because of leakages allowing grease to get in the stock.

Many Selectifier installations made use of automatic timers and valves on the reject line so only one unit is being dumped at a time, but the screens at Bucksport dump the rejects continuously. The Selectifiers reject up to 8000 lb. a day of fiber, with all but a very small fraction of this being recovered at the Jonsson screens. The Selectifiers reject a higher percentage of coarse stock than the older, overloaded Bird screens. With a Selectifier set up in parallel with a Bird screen the rejects were classified.

Results showed 50% of the Selectifier and only 20% of the Bird rejects being retained on a 20-mesh screen. The difference was in the amount of rejects passing 65 mesh with 70% of Bird Screen and only 40% of Selectifier rejects passing. Since the Selectifiers are fully enclosed there is also less chance of dirt getting into the stock.

Since the Selectifiers reject fiber bundles as well as coarse fibers, it is necessary that the good fibers making up the bundles be recovered. The recovery of good fibers is done on a Jonsson flat screen with rejects going to the sewer and accepted stock returned to the wire pit. The perforations are 0.063 in. The amount of stock being rejected varies with the height of stock in the vat. If the vat level is too high, too much good fiber is rejected while if it is too low, too many coarse fibers are pulled through with the accepted stock. Once the reject standard for each grade was set, tests were continued to check that the standards were being met.

Like all other types of screening and cleaning, the proper balance between cleanliness and cost must be met.

Presented at the Maine-New Hampshire Section of TAPPI, Portland, Me., Oct. 23–24, 1959.

Kalamazoo Valley

The first meeting of the Kalamazoo Valley Section of TAPPI was held jointly with the Michigan Division of PIMA on Oct. 2, 1959, at the Harris Hotel. Following an introduction of the officers of the two organizations, Olin W. Callighan, secretary-treasurer, Michigan Division, PIMA, presented the speaker Leslie L. Warner, Industrial Products Development Laboratory, Owens-Corning Fiberglass Corp., Ashton, R. I.

Glass Fibers and the Paper Industry

Leslie L. Warner

Glass fibers—some softer and finer than cotton, an amazing contradiction to the ordinary hard, shatterable material with which we are so familiar. Glass pliable enough to be twisted, woven, or knitted. Glass which retains all the familiar properties, cleanliness, inertness to the elements—fire and water, defies rot, mildew, and sunlight. Glass to be made into fire and ageproof draperies, sagproof insect screen, weatherproof boats, and even maintenance-free rain gutters and downspouts for buildings.

Glass fibers for numberless uses and at the Industrial Product Development Laboratory in Ashton, R. I., we try to learn what glass fiber can do in some of these numberless uses. We work individually and in teams striving to learn the effect of glass fibers in laminates, curtains, rugs, industrial fabrics, concrete, plaster, molding compounds, and everything imaginable.

My particular project for the past 3 years has been Fiberglas in paper. Glass fibers and wood pulp—What can glass do for the paper Industry? What will glass do in paper?

Glass fibers which are made under the closest of control can be made down to $^1/_2$ a micron in diameter. Glass fibers can be produced in wool form, staple fibers, spun roving, or in continuous strands all with similarity of chemical properties, but quite dissimilar in physical appearance and uses.

Glass fibers first entered the paper industry when a new and better filter material was needed. This new filter had to remove the smallest particles with the least resistance to flow. It had to be chemically inert to most gases. It had to withstand high temperatures and be uniform and reproducible. Glass was ideally suited chemically and glass fibers in such a wide variety of diameters theoretically could be designed into a perfect filter to do any filtration task. The problem

Leslie L. Warner, Industrial Products Development Laboratory, Owens-Corning Fiberglas Corp., Ashton, R. I.

was to blend and lay down in a feasible manner the glass fibers. What industry had the know-how, the experience, and the equipment? Who had been forming nonwoven materials since the Sphinx was part of a mountain. The paper industry of course. It was in the paper industry that the problems of glass fiber dispersal, blending, and bonding were solved, and filter material was and is produced to solve a difficult atomic energy filtration problem.

The wheels and cogs man calls a brain—resistors, coils, relays and switches, if medical research is on the right track—were in motion now—let's investigate glass fibers in paper, and a project was launched.

Owens-Corning Fiberglas sponsored a research project at The Institute of Paper Chemistry in Appleton, Wis. Back came a report and I quote, "It is doubtful whether any of the common use properties (of paper) would be sufficiently improved to warrant the inclusion of Fiberglas of the diameter and types used in this investigation."

Well, Owens-Corning Fiberglas management does not care for a "No" answer, especially when it carries qualifications. Let us carry the experiment further, use different glass fibers, different treatments, new and different techniques, prove the merits or the demerit of glass fibers in paper. To carry out this assignment, a contract was made with Forest Products Laboratory, Madison, Wis., for research with both handsheet studies and pilot machine runs. A handsheet laboratory was established at Ashton, R. I., complete with controlled atmosphere testing facilities. Lowell Technological Institute, Lowell, Mass., and Professor Norwood Keeny assisted and instructed us in the art of handsheet construction. A library of paper reference works was assembled and we proceeded to learn something about the art and science of papermaking. Many interested paper mills cooperated with us in our quest for knowledge—we were privileged to use the pilot machines at the New York State College of Forestry in Syracuse, N. Y., for a drainage and drying rate study. At Knowlton Brothers, Watertown, N. Y., paper was made to study the effect in laminates. Fiberglas paper has been made on wet lap cylinder machines, of as little as 16 tons per day output; it has been made on various fourdrinier machines, Rotoformers, on several cylinder machines—one of over 200 in. width and producing over 5 tons of board per hour. Pulps used have ranged from highly beaten sulphites to reworked newsprint, bagasse, and muslin rags. We have even dabbled in coating and sizing operations as well as beater additive studies of various materials from alum and starch to latex and resins. I mention these activities to show that work has been done to determine the value of Fiberglas in paper; now I should like to report some of the results accomplished in the exercise.

RESULTS

The result of the glass fiber-paper study indicated that first of all the glass fiber most applicable to paper is $1/4$ in. length 9 μ diameter treated with Binder 867, a soft chrome material. This yarn is commonly called 150's or 15,000 yd. of 204 filament strand weighs 1 lb. To be more spectacular, 1 lb. of 150's yarn contains 1738.6 miles of 9 μ glass fiber.

The binder is a material applied as the glass fibers are formed from molten glass to hold the 204 fibers together until processing is completed and the strands are chopped into $1/4$-in. lengths. The binder used in the glass fibers was, itself, the result of several months of effort, for it had three requirements, (1) it shall efficiently bind the glass fibers together for processing; (2) it must allow the fibers to disperse readily in pulp slurry; and (3) it should form either a glass to glass or glass to cellulose bond in the finished sheet.

Binder 867 met these requirements, as does PO36, its sister binder applied to spun roving. Now what does the addition of 2 to 10% glass fibers do for paper?

The first evidence of glass fibers effect on paper is an increase in stock freeness or drainage rate. Second, wet web strength is improved, drying rate is increased, machine shrinkage in both machine and cross-machine direction is reduced, usually by 4 to 5 in. on a 200-in. machine.

Once the paper has been made, what effect do glass fibers have on its physical characteristics?

The greatest change is in dimensional stability where glass fibers reduce moisture induced movement to half that of paper made without glass.

Porosity is increased by the addition of glass fibers and can be altered to fit specifications by combinations of pulp and various amounts of different type and diameter glass as indeed it is in the manufacture of filter media. Tear resistance is increased up to 3.8 times that of pulp alone especially with groundwood and short fiber pulps.

Density is usually reduced by the addition of glass fibers, whereas tensile strength, opacity, brightness, and burst strength are not effected greatly with $1/4$-in. fibers. Burst strength can be improved through the utilization of $1/4$-in. chopped spun roving providing fibers of lengths varying in length from $1/4$ to $1/2$ in. This spectrum of fiber lengths does not disperse as readily as $1/4$-in. chopped strand but good paper can be made with increased burst strength, plus the other qualities of glass fiber bearing papers.

Now glass fibers are not the answer to every man's paper problems and the disadvantages must be balanced against the advantages before launching on a project for their incorporation into your paper product. Formation is not improved with the addition of glass fibers, especially as addition reaches the 15 to 25% level, although paper containing 75% $1/4$-in. 9 μ glass fibers with good formation has been made on an 18-in. pilot machine and 90% glass fiber (using 5.5 μ wool fiber) has been constructed commercially with excellent uniformity.

Fold endurance is always reduced and 5% glass fiber causes a 50% reduction in fold endurance. This has been improved in handsheets by the use of a starch beater additive, but two machine trials could not reproduce these results.

Calendering a glassbearing sheet practically eliminates all the good effects of glass except dimensional stability in anything other than groundwood paper. We are not sure what does occur here because the glass does not appear broken in the calendered sheet but tear strength improvement has fled.

Another problem with glass fiber paper arises when printing occurs—glass fibers tend to shed from the paper surface into the ink, onto the plates or felts and poor reproduction results. This shedding problem can be solved through coating, sizing, and laminating where these operations are feasible in constructing a saleable product.

MACHINE ADDITION

How can glass fibers be added to a paper machine furnish? They can be added to a pulp-water slurry in much the same manner that glass is added to gypsum board and to mat producing machines by chopping continuously through a chopper designed to cut up to 700 lb. per hr. of 60 end roving. The machines can be set up to chop directly into the fully refined machine furnish. The specific point at which glass fibers are added varies with each machine installation, but in general, the glass can be added at the stock chest, the consistency regular chest, or the inlet to the final jordan. The point of addition must be after all refining is complete, and where sufficient agitation occurs to disperse the glass fibers thoroughly in the pulp. A jordan operated with the plug backed off is excellent for this operation.

Glass fibers have been dispersed in a beater where no roll pressure was being applied, in a 7% solids content pulp slurry up to a glass content of 10% on a dry fiber basis in only a few minutes, but usually dispersal and mixing is done where solids content is approximately 1.5%.

Glass fibers once dispersed in a machine furnish will not settle out if the pulp is allowed to stand motionless. They will not be removed in dirt removal devices and will pass

through screens having a slot width of 0.014 in. On wet lap cylinders the glass fibers cause some difficulty in cutting off the lap by impact but no difficulty is found in forming glass paper on conventional paper machines either cylinder, fourdrinier, or rotoformer. Any difficulty encountered is in the drying operation where draw adjustments are necessary to compensate for the greatly reduced machine direction shrinkage.

PAPER MARKET AND USE

Glass fibers are being used at a constantly increasing rate by the paper industry largely in paper where dimensional stability is a factor. Other uses are in filter media, impregnating papers, and specialty decorative papers. One potential use is in a magazine paper where the increase in tear and burst strengths obtained by a 2% glass fiber content permits a 13% increase in groundwood content and a 20% basis weight reduction while retaining the physical characteristics of the original sheet. This is an ideal use for glass fiber in the variety of ways the glass induced properties are utilized. First, the increased drainage rate and wet web strength enable easier construction of the lighter sheet with greater groundwood content. Then the increased tear and burst strength imparted by the glass fiber is enhanced by a sizing and coating application which bonds the fibers together for greater fiber strength utilization and increased fold endurance. The dimensional stability provided by the glass fibers reduces greatly the roll damage caused by moisture changes during transit and storage while curl and wrinkles are eliminated in the finished product.

In summation, glass fibers have been proved a useful addition to the conventional papermaking fibers. They are available in a variety of types, lengths, and diameters, each of which imparts certain properties to paper. The use of glass in overcoming dimensional stability, porosity, drainage rate, drying rate, or burst resistance tear strength problem depends on the imagination of those who make paper.

Glass fibers have merit in paper and merit your consideration the next time you meet a problem their unique properties might solve.

Presented at the meeting of the Kalamazoo Valley Section of TAPPI held in Kalamazoo, Mich., Oct. 2, 1959.

Delaware

On September 24, 1959, the Delaware Valley Section of TAPPI held its first meeting of the 1959–60 season. The section and its members were guests of the Downingtown Paper Co. and Downingtown Paper Box Co. in Downingtown, Pa.

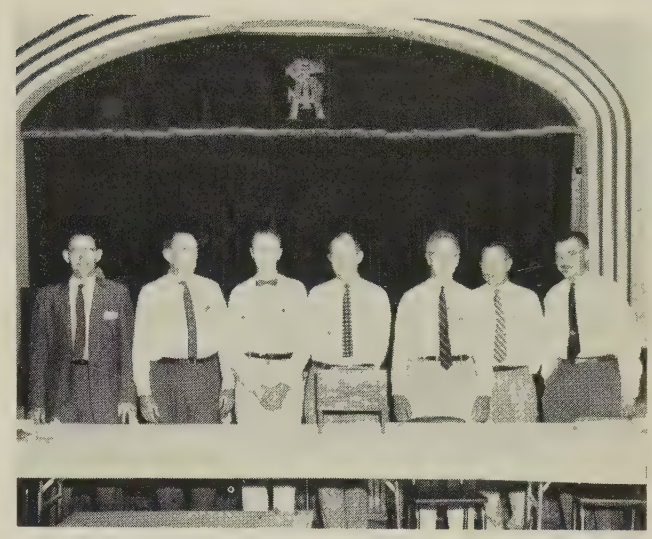
Tours of the Downingtown Paper Co. and Downingtown Paper Box Co. were conducted in the afternoon by company representatives. Of particular interest in these tours were the newly installed cylinder machine and the waste water treatment system of the Downingtown Paper Co.

A social hour and dinner were held at the St. Anthony's Lodge in Downingtown.

Following the dinner our section chairman, George Boger, expressed thanks on behalf of the Delaware Valley Section to the Downingtown Paper Co. and the Downingtown Paper Box Co. for the opportunity of visiting their facilities and for the technical program which they prepared. Mr. Boger then introduced Thomas E. Brookover, general manager of technical services for Downingtown Paper Co., who served as the master of ceremonies.

After his opening remarks, Mr. Brookover presented F. Houston McIlvain, president of the Downingtown Paper Co. Mr. McIlvain welcomed the DVS to Downingtown Paper Co. and expressed the hope that the following papers on Downingtown Paper Co.'s approach to waste treatment would benefit other organizations faced with waste problems.

James Field of National TAPPI next presented a TAPPI



L.-R.: A. L. Saindon, Curtis Paper Co.; J. Gibson McIlvain, Downingtown Paper Co.; George Boger, Jr., Amalgamated Chemical Corp.; S. Huston McIlvain, Downingtown Paper Co.; Thomas Brookover, Downingtown Paper Co.; John Peters, Downingtown Paper Co.; Stephen J. Lucas, Downingtown Paper Co.

Award to our 1958–59 chairman, Don Kane. Although Mr. Kane was unable to accept the award in person, the section enthusiastically applauded this recognition for the services Mr. Kane had performed as an officer of the DVS.

Following these ceremonies, Mr. Brookover introduced the speakers, John G. Peters, manager of technical control, Downingtown Paper Co. and Stephen J. Lucas, manager of design engineering, Downingtown Paper Co., the following papers were presented.

Technical and Biological Aspects of Waste Water Treatment at Downingtown Paper Co.

J. G. Peters

Waste-water treatment at the Downingtown Paper Co. started in 1937 with the installation of two concrete sedimentation basins each 60 by 400 ft. and an average depth of 7 ft. with a capacity of 1,000,000 gal.

At that time we had four paper machines with an average production of 230 tons per day and a waste discharge of 2,350,000 gal.

The suspended solids prior to the sedimentation basins averaged 2.4 lb. per 1000 gal. We had an average removal of 5400 lb. per day of suspended solids in the basins. Our effluent contained 0.1 lb. of suspended solids per 1000 gal., or 1.4 lb. per ton of production.

Alum, used as a coagulant for breaking up the colloidal matter in the waste water and settling the settlable solids, averaged 2000 lb. per day.

The basins at that time had an average use time of 4 months. At the end of this period, they were pumped to a drying lagoon, that in turn was cleaned yearly, the contents being hauled to our dump.

At the present time we have three paper machines with an average daily production rate to date of 305 tons, and a waste-water effluent of 2,550,000 gal. per day.

The suspended solids prior to the sedimentation basins average 5.8 lb. per 1000 gal., with a daily removal of 14,000 lb. of suspended solids in the basins. Our effluent contains 0.3 of a lb. per 1000 gal., or 2.8 lb. per ton of production.

Alum consumption averages approximately 3200 lb. per day.

The useful life of a bed is now approximately 1.6 months instead of the 4 months mentioned earlier.

During the past 20 years we have known more complete

J. G. Peters, Downingtown Paper Co., Downingtown, Pa.

treatment would be required, and this became a reality in 1957 when we received our directive from the Pennsylvania Sanitary Water Board. Therefore, during the past several years, we were interested in methods for complete waste treatment. A study of our waste water showed that we had an average B.O.D. of 150 p.p.m. ahead of the sedimentation basins with a 35% reduction in B.O.D. occurring in the basins, and a B.O.D. of approximately 100 p.p.m. in the effluent to the stream.

With the aid of Dr. Gehm and Dr. Lardieri of the National Council for Stream Improvement we constructed an activated sludge process pilot plant.

The kinetics of biological oxidation or organic wastes as described by Wes Eckenfelder is assumed to be a three-phase process as follows:

1. An initial high rate removal of B.O.D. on contact with biologically active sludge. The extent of the removal depends upon the sludge loading ratio and the ecological condition of the sludge.
2. Removal of B.O.D. in direct proportion to biological cell growth. For any organic substrate, a portion of this B.O.D. removed is synthesized to new cell material, and the remainder is oxidized to provide energy for this synthesis.
3. Oxidation of biological cell material through endogenous respiration. The initial removal of B.O.D. occurs in 1 to 20 min.

This sketch illustrates the design and volumes of the pilot plant. It was hoped that we would have a capacity of 50 g.p.m., but we have never been able to operate efficiently above 18 g.p.m.; and we find 15 g.p.m. a practical maximum.

We are operating the pilot plant on an untreated effluent from a link belt saveall operating on our no. 2 and no. 3 mill effluents. This combined effluent contains approximately 110 p.p.m. of suspended solids, a dissolved solids content of approximately 600 p.p.m. containing 45 to 55% organic, and a B.O.D. of approximately 135 p.p.m.

The only chemical being used in this process is diammonium phosphate and this is used as nutrient for bacteria growth.

In starting up an activated sludge process our procedure is as follows:

1. Check equipment to see if it is in good operating condition.
2. Fill system with water to be treated, stopping influent when system is full.
3. Start aerating equipment when water level approaches height of the diffuser aerators. Continue aerating for 24 hr. before adding seed.
4. Turn-in nutrient feed to aeration tank.
5. Turn-on the return sludge line.
6. Aerate seeded waste water in system for 24 hr.
7. Turn-in influent.
8. Reduce return sludge flow to approximately 6 g.p.m. At a rate of 15 g.p.m. of influent and 6 g.p.m. of return sludge, the retention time will be approximately 6 hr.

In operating an activated sludge process our procedure is as follows.

1. Feed nutrient at the rate of 0.1 lb. of diammonium phosphate per 1000 gal. influent. In full scale operation we anticipate feeding one part of nitrogen as ammonia to 40 parts of B.O.D., and phosphorus at a rate of one part to 120 parts of B.O.D.
2. Add air at a rate of 1.5 to 2.0 cu. ft. per gal. of influent.
3. Operate the aeration tank with a mixed liquor volatile suspended solids of 3500 to 5000 p.p.m.
4. Operate the return sludge with a concentration of 10,000 to 12,000 p.p.m.
5. Sludge from the clarifier will have to be wasted at a rate of approximately 200 g.p.m. to keep the return sludge at the proper concentration after optimum conditions are attained.

The following tests were set up to obtain data on the plant's operation.

1. Suspended and dissolved solids on influent and effluent.
2. Suspended and volatile solids on mixed liquor and return sludge.
3. Five-day B.O.D. samples on influent and effluent.
4. Dissolved oxygen in influent, aeration tank, top of clarifier, and effluent. (Keep an excess of dissolved oxygen in the aeration tank.)
5. Turbidity of the effluent.
6. Temperature in influent, aeration tank, return sludge, and effluent.
7. Check pH of influent and effluent.

We have had a fairly successful operation in the pilot plant. For the most part:

1. B.O.D. has been reduced in excess of 90%.
2. Turbidities in the effluent have been running from less than 25 to 75 p.p.m. In our opinion when higher turbidities occur, they are due to sludge bulking and carryover in the effluent.
3. Suspended solids in the effluent range from 0 to 30 p.p.m. with an average reduction of 85% between influent and effluent.
4. Dissolved solids are reduced approximately 50%.
5. Titanium dioxide concentration in white water from paper mill effluents is greatly reduced by this process.
6. Many colors, including carbon black, in white water from paper mill effluents are greatly reduced in concentration by this process.

Some difficulties have been encountered and we are certain that other problems will arise during the winter months.

1. The pilot plant was originally designed using an air lift for return sludge. Because of build-up of sludge solids with consistency changes and increased viscosity this was not dependable. Dependability was made possible by a Moyno positive displacement pump.
2. Oil in our mill air supply caused bacteria kill and floating sludge. This condition was very much improved by oil filters and weekly cleaning of these filters.
3. Bulking of sludge over a plant shutdown—this was very much reduced by stopping nutrient feed and reducing the air to lower the activity of the bacteria growth. We are going to experiment with changes in shutdown procedure to see if improvement might be attained.
4. Lack of the ability of know-how in dewatering sludge. We have done some work that could be considered successful. We determined the amount of sludge we could expect along with the amount of fly ash obtainable from our power plant, mixed the fly ash with sludge in these proportions and filtered on a vacuum leaf filter with good results.

We also obtained fair results on a vacuum leaf filter when 2% $FeCl_3$ was mixed with the sludge.

Full scale plant sludge disposition, however, remains unresolved.

At this time I want to thank Dr. Gehm and Dr. Lardieri of the National Council of Stream Improvement and Wes Eckenfelder for their personal assistance and Robert Forrest of our laboratory who has done most of the work on this project.

We also found the text, Biological Treatment of Sewage and Industrial Wastes," published by Reinhold, and "Bio-oxidation of Organic Wastes: Theory and Design," written by Wesley Eckenfelder and Donald O'Connor of Manhattan College to be excellent references in the treatment of industrial wastes.

Presented at the Delaware Valley Section of TAPPI, Downingtown, Pa., Sept. 24, 1959.

45th Annual Meeting

Hotel Commodore, New York, N. Y.
Feb. 22–25, 1960

Mechanical Aspects of Industrial Waste Treatment at Downingtown Paper Co.

Stephen J. Lucas

The Downingtown Paper Co. is located in Downingtown, Chester County, Pa., on the East Brandywine Creek, a stream requiring reduction in polluting characteristics of industrial wastes equivalent to complete treatment of municipal sewage. The company manufactures paperboard on three cylinder-type machines, converting wastepapers and pulp into approximately 305 tons daily of finished board. Process water is used as a medium of hydration and transport for the paper fibers until they are deposited on the paper forming wire. The white water containing filler and fine fiber passes through the wire and is collected for re-use or released to waste. In addition to the process water used in paper manufacture, water is also used in the power house for make up of leakage, steam loss to process and continuous boiler blowdown.

WATER SUPPLY

The water supply for the company is obtained from two sources, the Borough of Downingtown municipal system and the East Brandywine Creek. The Borough supply is used for drinking, sanitation, and stand-by fire protection, the average daily usage being approximately 20,500 gal. The Brandywine Creek supply is used for industrial process and power plant purposes with an average intake of 3,000,000 gal. per day. Traveling screens, a clarifier, and chemical treatment are available at the creek water intake to insure desired quality of incoming water.

SEWAGE & INDUSTRIAL WASTES

Waste waters from the company are handled according to their origin. Sanitary wastes are returned to the Downingtown Borough sewer and treated in the municipal sewage system. Solids from the power house blowdown are settled out in a small basin and the water is returned to the creek. Mill waste water is given primary treatment by the company and returned to the Brandywine. Characteristics of the raw mill waste were ascertained over a period of time by competent technicians employed by the company technical control department and chemistry laboratory, using accepted methods and calculations for obtaining such data. In addition, Downingtown Paper Co. tests have been verified in the past by state lab analyses. Waste water data and methods for determining such data are as follows:

1 Design flow rate—2100 g.p.m.—continuous recording over a rectangular weir. This flow rate, equalling 3,000,000 gal. per day, was selected to give ample capacity for future company growth.

2. Design load
   a. B.O.D. load of 5000 lb. per day—standard 5 day B.O.D. test.
   b. Suspended solids—700 p.p.m.—those filterable on asbestos pad in gooch crucible.
3. pH—Beckman pH meter
   a. Average in 1958–6.5
   b. Monthly range usually—5.0 to 7.5
   c. Extremes in 1958—3.8 and 9.4 (short duration).
4. Temperature—continuously recording thermometer. The average monthly temperature is seasonal and has ranged from 85°F. in winter to 116°F. in summer. In any month, the average daily temperature range will be 20°F. Short term temperature changes of more than 5°F. in 15 min. are rare.

EXISTING TREATMENT

The company, since 1937, has operated waste treatment works which afford primary treatment to its industrial waste water. The existing works consist of a surge pit and bar rack; an alum feeder; two pumps, one operating continuously and one with automatic on-off action to handle peak loads; two sedimentation beds, each essentially 400 ft. long by 60 ft. wide by 7 ft. deep with 1,000,000 gal. capacity; and a huge lagoon. Alum solution is fed in appropriate amounts to the raw waste water just before the pumps. The waste is then pumped to one or both of the two sedimentation beds where the floc is allowed to settle out in a maximum retention time of 16 hr. When one bed becomes full of settled solids, the other must handle the full load until the concentrated solids are pumped from the full bed to the lagoon. The bed is then ready for re-use. The thickened solids in the lagoon are loaded into trucks and hauled to the company dump once a year. Effluent from the sedimentation beds is released to the stream with no further treatment. The existing treatment effects a suspended solids removal of 95%, the final effluent containing 46 p.p.m.; and a corresponding reduction in B.O.D. of 35%, the final effluent containing 102 p.p.m. These figures are averages.

PURPOSE OF NEW TREATMENT WORKS

The Sanitary Water Board on March 4, 1958, by registered mail, directed that the Downingtown Paper Co. "on or before August 15, 1958, to submit to the Board for approval, a report upon and plans for works to provide treatment of your waste waters to effect a reduction of their polluting characteristics equivalent to the complete treatment of municipal sewage. The Board further directs that your company submit a time schedule for the construction of such works." The company complied with the order and on March 5, 1958, was notified that the Sanitary Water Board had issued a permit for the proposed installation.

Proposed Treatment

In order to provide the required treatment of its industrial waste water, the company proposes to modify and add to the existing treatment works so that the following flow pattern for a bio-oxidized sludge system will result. Physically, all of the existing installation will be used. In addition, primary and secondary clarifiers will be installed and the east sedimentation bed will be divided into two 200 ft. long by 60 ft. wide basins with aeration piping in both halves.

Existing pumps will pump the raw waste to a flat plate screen for removal of large particle size material and floating debris, and a grit remover for removal of heavy matter, thence to a primary clarifier. Effluent from the clarifier will flow by gravity to the approach trough at the north end of the east (aeration) basin, mixing in the trough with inoculating sludge from the secondary clarifier and nutrients. During normal operation of the aeration system, the waste will travel the complete length of the beds, flowing over the center wall and continuing until the full 400 ft. of aeration bed length have been covered. The mixed liquor will flow by gravity out of the south end of the bed to a mixed liquor clarifier. Effluent from the clarifier will flow by gravity to the creek. A centrifugal pump, located after the sludge waste valve, will return inoculating sludge to the approach trough at the north end of the beds. Either half of the aeration basin may be shut down at any time for repairs or inspection.

The existing west sedimentation basin will be used as a surge basin for peak flows of effluent from the primary clarifier. A low-volume pump will pump from the surge basin into the aeration approach trough in order that flow through the aeration bed will be as uniform as possible.

Primary and secondary sludges present problems which are as yet unsolved and will remain so until actual amounts, consistencies, and thickening characteristics are observed.

Proposed Equipment

Major equipment to accomplish the above requirements will be as listed below. Sizes were determined mainly from ex-

Stephen J. Lucas, Downingtown Paper Co., Downingtown, Pa.

perience in the operation of a Link Belt sedimentation system and an activated sludge pilot plant operating on this particular waste and upon which the company reported on a monthly basis to the Sanitary Water Board.

1. *Primary Clarifier*
   a. 115 ft. diameter by 10 by 17 ft. 8 in.
   b. Rise rate—300 gal. per sq. ft. per day
   c. Retention time—8 hr. The design rise rate may seem low and retention time may seem high to many consultants in the waste treatment field but it has been found in this instance by plant operation that this particular waste operation will be satisfactory.
   d. Weir length—355 ft.
   e. Skimmer, scum troughs, and scum baffle.
   f. No chemical treatment.

The need for a primary clarifier was originally questioned since removal of suspended solids was being accomplished in the existing sedimentation beds, it being felt that effluent from these beds could flow directly to an aeration basin. However, sedimentation basins do a good job when they are clean but when solids build up, retention time is lost and suspended solids overflow increases due to the loss of bed efficiency. It had been determined that suspended solids greater than 100 p.p.m. would be harmful to the activated sludge process, therefore a clarifier with its continual removal of sludge and maintenance of high efficiency was necessary. In addition, sludge handling from a clarifier offered much greater simplicity at lower cost than periodic cleaning of the sedimentation basins.

2. Aeration System
   a. Total of 20 cross headers on 20 ft. centers along bottom of existing east settling bed. Each cross header to be provided with 20 spargers on 23 in. centers; or equal.
   b. Two turbine compressors—4200 cu ft. min. 5 p.s.i.g., 150 hp.
3. Nutrient System
   a. A nutrient system will be installed to feed nitrogen to the aeration bed inlet at the rate of 1 part of nitrogen per 20 lb. of B.O.D. and 1 part of phosphorus per 80 lb. of B.O.D.
4. Secondary Clarifier
   a. 135 ft. diameter by 10 ft. and 17 ft. 10 in.
   b. Rise rate—200 gal. per sq. ft. per day.
   c. Retention time—8 hr. The design rise rate may seem low and retentiom time may seem high to many consultants in the waste treatment field but it has been found in this instance by pilot plant operation that this particular waste operation will be satisfactory.
   d. Weir length—424 ft.
   e. Skimmer, scum trough, and scum baffle
5. Sludge Thickening. It is felt that no concrete decision can be made until character and volume of both primary and secondary sludge are observed in actual operation of the treatment plant.

ANTICIPATED POLLUTION REDUCTION

1. *Primary Clarifier System*—Anticipated results are elimination of junk and floating matter and reduction of suspended solids to less than 100 p.p.m. These requirements were shown by pilot plant work to be necessary for proper bio-oxidation sludge treatment of the industrial waste of this particular company.

2. *Aeration System and Secondary Clarifier*—Anticipated results from the aeration system and secondary clarifier, acting together, are practically complete removal of all suspended solids; a minimum of 85% reduction in B.O.D. load; and a final effluent that is suitable for discharge into the East Brandywine Creek.

The permit requires that the four phases of this installation be completed in the following manner:

1. Primary treatment and primary sludge handling to be installed and operating by Sept. 1, 1959.

2. Secondary treatment aeration installation to be installed by Dec. 31, 1960. When the aeration system is installed as the second phase, it will be used as a stabilization basin until the third phase, the secondary clarifier, is installed. 200,000 gal. per day will be taken from the primary clarifier effluent and passed through the 1,000,000 gal. aeration bed, allowing 5 days retention before flowing into the creek. The remainder of the primary clarifier effluent will flow to the creek without further treatment.

Anticipated pollution reduction here will be the complete treatment of at least 200,000 gal. per day of mill waste water. The stabilization basin method has been accepted in some cases as affording complete treatment of paper mill wastes.

3. Secondary treatment clarifier completion date dependent upon phases 1 and 2.

4. Secondary treatment sludge handling installation contingent upon phase 3.

Detailed engineering was performed by Gilbert Associates, Reading, Pa., on phase 1, the primary clarifier and began soon after the permit was received. It is obvious that the September 1st date could not be held because of the late date at which the permit was received. The Board recognized this and accepted a later date as long as the work proceeded expediciously. On Sept. 14, 1959, a contract was entered into with Binkele Construction Co., Lancaster, Pa., for construction and installation of a Graver clarifier and its system. Expected start-up time for this unit is Dec. 15, 1959.

Presented at the Delaware Valley Section of TAPPI, Downingtown, Pa., Sept. 24, 1959.

Question: Can sludge be dewatered by centrifugal means?

Answer: Primary solids can be separated on a centrifuge, but secondary solids which contain chemically bound water cannot be easily separated in this way. The solids content of sludge could be increased only from 1 to 4 or 5% by centrifugal methods.

Question: What does an installation of this type cost?

Answer: $500,000.00

Chicago

The meeting was held on October 6 at the Chicago Bar Association and the attendance was excellent for the first meeting of the new season.

The meeting consisted of a panel of speakers discussing the subject of "New Aspects of Paper Coating." A. L. Magnuson of Potlatch Forests, Inc. was moderator for the panel.

First speaker was Walter Moeller of National Starch & Chemical Corp. discussing "Resin-Starch Binder Systems in Clay Coatings."

"Plain Talk on Polyethylene" was the topic presented by F. R. Lehman, Coatings Technical Service, Dow Chemical Co.

A question-and-answer period concluded the evening's program.

Southeastern

The meeting opened with a welcome by R. L. Bentley, resident manager of the West Virginia Pulp and Paper Mill in Charleston, S. C. R. R. Chase, section chairman, reminded the group of the section's Technical Paper Contest Deadline for this year's contest is Feb. 1, 1960.

R. A. Flick, vice-chairman, and Mr. B. Reaves, program chairman, presented certificates to all participants in the past two contents. These included:

T. L. Gilles, Brunswick Pulp and Paper Co., Brunswick, Ga.
J. O. Mallory, Union Bag-Camp Paper Corp., Savannah, Ga.
J. F. Turner, West Virginia Pulp and Paper Co., Charleston, S. C.
T. R. Johnson, Jr., Riegel Paper Corp., Acme, N. C.
A. L. Pickens, Buckeye Cellulose, Foley, Fla.
W. S. Shalow, Buckeye Cellulose, Foley, Fla.
J. H. Smith, Southern Paperboard, Port Wentworth, Ga.
R. F. Perkins, St. Regis Paper Corp., Pensacola, Fla.
J. C. Robertson, Sunoco Products, Hartsville, S. C.
J. C. Thurmond, Union Bag-Camp Paper Corp., Savannah, Ga.
O. J. Bristow, Union Bag-Camp Paper Corp., Savannah, Ga.
R. Schmut, West Virginia Pulp and Paper Co., Charleston, S. C.
J. E. Wisenhunt, Sunoco Products, Hartsville, S. C.

Winners of the 1958–59 contest were awarded prizes. They were:

J. C. Thurmond, Union Bag-Camp Paper Corp.
O. J. Bristow, Union Bag-Camp Paper Corp.
J. E. Wisenhunt, Sunoco Products

Both papers were awarded a first prize.

A tour of the West Virginia Pulp and Paper Mill was conducted on September 26.

Custom-Made Defoamers

E. S. Rice

In the writer's experience in the pulp and paper industry, I have come across numerous associates who have the miracle cure for all our ills. In many cases chemicals are developed from laboratory-scale experiments and are given to various salesmen to sell to paper mills as a positive cure for slime, foam, strength development, drainage, drying capacity, speed, etc. However, far be it from me to be critical of continual laboratory or research efforts of companies to provide us with aids to our problems, but may I beg of them to approach us in this manner: "We understand you have a problem of such and such a nature" or "Do you have a problem of such and such a nature?" If so, then go on with the theme that they are manufacturers of chemicals that have been applied successfully to various problems, but that they first would like to investigate the problem thoroughly, then possibly custom-make the chemical for the particular conditions in any given mill.

I might say here that the companies in the defoamer business apparently are more open minded about custom-made products than are some other suppliers who supply standard chemicals that are supposed to be successful in all mills, regardless of conditions and whose products have not been changed chemically for 25 or 30 years.

To point up the last statement, I would like to cite wet-end additives of whatever nature they may be. These chemicals came on the market during a time when mills were forcing their papermaking equipment beyond their capacity. For reasons unknown at the time and still unknown in many cases, benefits were noticeable and to the production people these additives became a crutch and one of the standard chemicals needed for papermaking.

However, when the pressure for production was reduced and a few more modern machines were being installed, the effectiveness of these additives became less apparent. Why? To go into this would take too much time, but regardless, we still find companies trying to sell these chemicals and in areas where technical advice or knowledge is not recognized, we have mills raising their cost of paper production $2.00 to $5.00 per ton, not because they absolutely need the chemical but because it is felt that it does help but there is no scientific proof to sustain it.

The same attitude exists in regard to defoamer to some degree, but in the last 2 years at our location we have experienced terrific results from the attitude of a number of companies that worked with us on a foam problem that the approach and solution to the problems have to be from a custom-made point of view.

Soon after the start-up of the Seminole Chief, we began to experience a build-up in chests, pipes, and refiner disks of a chocolate-brown layer-like material. In some places, it would be as thick as 2 to 3 in. It would then break away and show up in the liner sheet, plug the wire, build upon the presses and cause the machine to be shut down for extended periods for cleaning.

What was this material? Where was it coming from? What was so much different from the no. 1 machine system which was parallel to the new system, the only noticeable difference being that higher yield pulp was being cooked on one side than the other?

Samples of this chocolate-brown material were analyzed by various outside laboratories and the material was found to be very high in calcium soaps, calcium carbonate, organic material, and some pulp fiber. Through the course of investigating it was also found that the white water addition of defoamers was changing in degree of hardness. By this time four large manufacturers of defoamers were working on the problem, as it appeared early in the game that the big major difference in the two systems was that more defoamer was being used on one side than the other. This was being caused by major differences in mechanical action the pulp and white water were receiving and also because there was more chemical loss from the washers on one side than the other. But what difference should this make? The same defoamer was being used on both sides with the same water supply and yet no trouble on the number one side.

The main difference appeared to be that we had reached a saturation point on the no. 2 side by the need of defoamer where its concentration in the white water was at a point which a side reaction resulting in precipitation of the defoamer base was taking place.

Following are excerpts from letters from the defoamer companies:

"Briefly, all defoamers contain one, two or three insoluble products which possess high defoaming activity. It is necessary to disperse these materials to make them work effectively. Among the materials which may be used as dispersing or emulsifying agents are a variety of anionic materials such as the alkali metal and ammonium soaps, sulphated and sulphonated materials, etc. Nonionic polyethylene glycol ethers and esters may also be used. It was found early in this work that the most effective defoamers for kraft stocks employed alkali metal soaps as the emulsifier. These are particularly susceptible to precipitation by the hardness of the water. When calcium reacts with the fatty acid in the emulsifier, the emulsifier is converted to an insoluble material. Its emulsifying power is lost and the insoluble portions of the defoamer, along with the calcium soaps, are kicked out of the emulsion and appear as a curd.

"It was then concluded that the deposit was either coming from pitches or resins left in the pulp and their subsequent reaction with the hard water might be partly caused by the antifoam materials being used in the mill at the time. The antifoams being used at the time were of the fatty acid ester type and would readily form lime soaks which were insoluble. Various antifoams were screened in the laboratory and any resultant precipitate was noted. It was found that certain types of antifoam did not readily precipitate and apparently had no reaction with the calcium either in the stock or in the make-up water."

Along with the fact that the bases of defoamers being used at the time were reacting with the hard water, the mill itself had conditions that could lend to a precipitate being found from fatty acids and tall oil material being carried over from the washers. These compounds which were more in evidence on the no. 2 side than the no. 1 side, the cause of the higher chemical loss, would also form a precipitate with hard

E. S. Rice, St. Regis Paper Co., Pensacola, Fla.

water and form a deposit, but not such a degree as to be of much trouble until defoamers reacting in the same way raised the concentration to a point where wholesale precipitate took place.

The end result was and is that the various companies realized that a custom-made defoamer had to be manufactured for this mill. This first major change was to oil-base, liquid defoamers in place of paste-base defoamers. Then incorporated in their defoamers would be sequestering or dispersing agents to help prevent accumulation of any precipitate.

To aid in overcoming the possibility of chemicals left in the pulp adding to the problem, we have added a dispersing agent to the pulp but as washing is improved, mechanical causes of foam are corrected, the need for dispersing agents, and defoamers is decreased.

I hope the foregoing has in some way indicated how important it is for chemical suppliers to take the attitude that although they are experienced in a given field, the same problem in each mill has to be treated separately with the view that their specific chemicals may have to be custom-made to solve the problem method of measuring with plates.

Presented at the Southeastern Section of TAPPI, Charleston, S. C., Sept. 25–26, 1959.

Quality Control in the Manufacture of Corrugated Containers

G. C. Lecky

Quality control has just one function—that is to help the production department accomplish their mission of manufacturing the best possible product at the least possible cost.

To do this the quality control department must:

1. Set up quality standards for both raw materials and finished product.
2. See how these standards are being maintained by means of testing, and evaluation of those tests.
3. Pass this test information on to management and production in such a manner that action can be taken when material does not meet these standards. This phase of the quality control job is one of the hardest to accomplish. Too little detail does not give enough information on which to act and too much detail overwhelms the person who has to take action and he does nothing.

In the Container Division of St. Regis Paper Co. we have a quality control laboratory located in Crafton, Pa., just outside of Pittsburgh. This laboratory is well equipped and has an able staff under the supervision of the Division Quality Control chief, Don Johnson.

This laboratory carries out a testing and quality evaluation program for both raw material components and the finished product.

At the present time our components testing program consists mainly of tests on our paper. Paper tests are usually made on out-turn samples which are conditioned in accordance with ASTM and TAPPI Standards.

TESTS RUN

The usual tests run are:

a. Basis weight
b. Caliper
c. Mullen
d. Printing index
e. Tearing strength
f. Concora medium test
g. Water drop test
h. Chemical tests

Printing Index. This is a method of comparative evaluation for the printing properties of linerboard. The procedure is to drop a measured amount of a standard paraffin oil onto a liner surface held at an angle of 70°. When the surface sheen of the oil has disappeared, the oil stain is measured in tenths of an inch in two directions: length and breadth. The length measurement divided by the breadth measurement will give an empirical value which will indicate the printing properties and is referred to as the Printing Index. There has been no attempt, at this time, to set limits for this test, as its intended purpose is strictly comparative. It has been established that the higher the Index the better the printing surface; however, it is not known if there is a lineal relation inasmuch as the degree of printing performance is difficult to define.

Tearing Strength: This is the resistance of paper to a continued tear that has already been started by a knife cut. The testing instrument is an Elmendorf tear tester which exerts the force through a pendulum action and will indicate the results on a circumferential scale with a friction pointer.

The tear test on a chip liner will indicate, to a degree, the quality, in terms of the kraft to low grade waste relationship in the finish. A higher percentage of kraft clippings will increase the tearing resistance. Although it has not been definitely proved at this point, there is an indication that there may be a relation between tearing resistance and slotting performance on partitions. Past experiences tend to indicate there may be a maximum limit, as well as a lower limit, on tearing resistance, at which point one might expect to get ragged slots where a partitions slotter is employed.

Concora Medium Test: This is a recently developed test that is becoming widely accepted as a preview indication of the performance quality of corrugating media in the term of rigidity. A 6 by $^1/_2$ m. sample of medium is formed into 10 "A" flutes in an instrument known as the Concora medium fluter. A comparable strip of $^3/_4$ in. wide pressure sensitive tape is affixed to the fluted sample, in a specially designed rack and comb to avoid distortion, resulting in a 1.67 sq. in. sample of single-face board. After fluting the sample is conditioned at standard conditions for no less than 15 min. or more than 30 min. and is then submitted to a conventional flat crush test. The results can be reported in pounds required to fail the sample, which is usually referred to as the CMT Number or can be converted to a unit force by dividing the pounds (CMT No. by the area (1.67 sq. in.) to yield pounds per square inch.

Water Drop Test: This is a method of evaluating the water receptivitiy of corrugating grades. A measured amount of temperature controlled distilled water is dropped from a controlled height onto both sides of the sample and the average time in seconds from the time of dropping to the complete absorption of the surface water is recorded as the water drop. It has been established that when this time exceeds 45 sec., there is a good probability that difficulty will be experienced in forming the flutes on the corrugator.

Chemical Tests: Determinations of pH, reducible sulphur, soluble chlorides, sulphates, etc., are performed periodically.

Recording and Reporting of Tests

A control type chart is used daily as a cumulative laboratory record and deviations from the normal curve are reported to the production coordinator's office as soon as they appear significant. A weekly report on the individual suppliers is reported to management. This report contains the results of the tests made in that week, the weekly average, and conformance to the grade average by means of an index percentage. The grade average is the 6-month average reported for the previous half year. A composite monthly report is distributed to the plant managers, superintendents, and quality control representatives. Specific information on any grade or supplier is furnished immediately on request.

If at any time the laboratory tests indicate an individual shipment may have a serious deficiency in physical properties, the quality representative or superintendent of the plant receiving the shipment is notified by teletype with a confirming written report to the production coordinator's office, with as

G. C. Lecky, F. J. Kress Box Co., Pittsburgh, Pa.

much specific information as possible so that this information becomes a part of our permanent quality records.

Standards are set up on raw materials on the basis of analysis of previous tests and finished product requirements, such as freight classification requirement on Mullen, and good printing requirements.

Standards for the finished product are based on analysis of actual production quality and customers' requirements. In general, we say that good quality is that quality that can be maintained when we start out with good raw material and fabricate it properly with equipment that is in good operating condition.

Plant samples of the finished production are sent out to the central control laboratory where they are given physical tests such as:

A. Mullen
B. G.E. puncture test
C. Pin adhesion
D. Flat crush test
E. Caliper of combined board
F. Compression test of the set-up box

G.E. Puncture Test. In this test we measure the resistance of the combined board to rupture by a pyramidal object. The results are in inch-pounds per inch of tear, but are referred to as units for easy reference. This test generally is expected to yield the same test as the Mullen, and results under this figure indicate poor fabricating.

Pin Adhesion. Is a measure of the efficiency of the adhesion between the corrugation and liners.

Flat Crush Test. Is the amount of load usually expressed in pounds per square inch that the combined board will stand without failure.

Compression Test of the Setup Box. This is the load (in pounds) that a box can stand without a stated change in dimension in the direction which the load is applied. Usually $^3/_4$ in. on the top-to-bottom load and $^1/_2$ in. on the end-to-end load is considered the maximum deflection that a box should have before reaching its maximum load.

Results of these tests and how they compare with our standards are sent to management and the plants concerned.

Quality features not covered by the foregoing testing procedure can be evaluated by a quality rating system as follows:

The laboratory also receives from each of the plants samples of their finished production which are tested and rated for quality on the basis of a demerit rating system which will be discussed later. Results of these tests are sent back to the plants concerned and consolidated monthly on a report which shows how each of the plants rank quality-wise.

In the plants, quality standards can be maintained by means of a sampling and demerit rating system. The extent of the sampling will vary with the size of the individual plant operation. Rating corrugated quality by a sampling method is actually a very simple process. At regular intervals, a sample is picked up from each machine on which a check is to be made. The only important feature in this is to be sure that no selection of the sample is made. The inspector merely picks up a piece without making a choice between one and another, and checks the sample. By recording on paper the defects obtained in that sample, and by repeated sampling, we obtain an index of the quality being produced.

Everyone has in his own mind certain features to look for and certain standards by which he judges a case. All we do is set down these features and define the standards.

In order to set down what features we should grade for, we must first break down the product into its component operations and decide which are important to the over-all quality. In doing this we must make sure we cover all the points which could give us trouble, but at the same time keep our inspection as simple as possible. Also, we know that there are degrees of seriousness in defects. A slight deviation might not impair the usefulness of the product, while a wider deviation could render it useless. Therefore, any system of rating quality that is set up must also take this into account.

We have attempted to solve this problem by using a demerit system of rating quality which we have based on ideas contained in a Bell Telephone Laboratories reprint dated May, 1928, titled, "A Method of Rating Manufactured Products," by H. F. Dodge. The statistical background and method of computing quality limits are contained in this reprint.

In this method the defects are separated into three different classes according to their severity. Each class is assigned an arbitrary number of demerits. The following are the classes into which we separate our defects:

Class A (Two demerits) Minor defects—Defects which detract slightly from the appearance or performance of the product, but which will not in any way affect its usefulness.

Class B (Ten demerits) Serious defects—Defects which might give some trouble to the customer, but the product can still be used with some extra effort on his part.

Class C (Fifty demerits) Very serious defects—Defects which would be cause for customer rejection of the product.

These various classes have been defined for individual defects by actual measurements when possible, however, as you all realize, many of our potential causes of poor quality are not measurable by written standards, and so a set of visual standards must be set for this class of defects.

As we mentioned before, we rate both samples sent from our plants, and actual production at the machines, by the same system. First, we divide the defects into the different operations such as corrugator, slitter, and printer. Then we make a further breakdown of these operations to the factors which we think most directly affect the quality of the case. As you can see, we have not covered all the things that could go wrong, but only the major factors. The inspector, when rating a case, looks for each defect listed, and if he finds one that does not meet our standards, checks to see what class it falls in and enters there the appropriate number of demerits. The total number of demerits divided by the number of samples checked gives a *demerits per case* quality rating.

At the plant we use the same system, but in a slightly different form. Here of course, we list only the defects which pertain to that operation. Sample forms for the printer-slotter are left at the machine during the day's operation, together with any sample that has been graded. This gives the machine operator a chance to become familiar with our standards. A weekly consolidation of these results is made and copies sent to interested parties.

When more than one crew is involved in a day's operation, it is possible to obtain a rating for each operator as well as the machine involved. If one operator shows a high unit demerit average while the other show low, we can almost be sure that the trouble is not in the machine, but lies with the operator; whereas if all the operators show high demerit averages, we suspect the machine and have it checked by the maintenance department. The proper time to change parts (such as slotting knives) can be checked by observation of that particular rating. For example, when a machine has a new set of slotting knives installed, the slotting should all be clean and have a low demerit rating for clean slotting. As time goes on, obviously the demerits per unit for slotting should begin to rise. Observation of this rating over a period of time will give us the experience necessary to set up quality rating limits which would tell us when the knives need regrinding or replacement.

The corrugator is probably the most important machine as far as determining quality is concerned. It is not only the first operation, but poor board cannot be satisfactorily fabricated in succeeding operations, resulting in excessive waste and poor quality boxes. We put special emphasis on this operation. We not only rate the machine by our quality rating system, but we also have samples of production sent at regular intervals to the plant laboratory where they are calipered and flat crush run. A drop in these tests in always an indication of trouble at the corrugator, which, if caught before it be-

comes too serious, can save you a lot of plant trouble both productionwise and qualitywise.

Quality charts are placed at each machine and quality averages for each operator are posted each week. In this way, each operator can see his rating in relationship to the rest of the operators, and how the production from his machine compares with the production from other machines. Also, as the quality man rates each sample, he puts it and the grade beside the machine where the operator can see it. In this way each operator is trained to know what our quality standards are, and how near he is to meeting them.

As you can see, our approach to this problem has been to train the people to know what standards of quality we expect and to teach them to operate their equipment at these quality levels. In our operation where most material is taken from the machines by hand, there is sufficient time for each operator to inspect his work and make any changes necessary to assure a quality job. Quality control does not try to relieve the production department of its responsibility for maintaining quality, but gives it a tool which it can use to solve the problem itself.

The foreman, if he uses this information correctly, can see what operators need his supervision most, and what equipment should be next in line for maintenance.

There is always the danger when using visual standards that our concepts will change, and one person will be grading differently than another as time goes on. We have tried to combat this by having the laboratory continuously grade random samples of finished production. The grades arrived at for the various operations are compared with those the plant comes up with. If there is an appreciable difference between the two average grades, we check to see who has wandered off the standard.

We are continuously revising our standards, usually upwards, due to better equipment, improved production methods, complaints, and comments from the customers.

In conclusion, I would like to sound a warning that no quality control method ever improved quality by itself. Proper use by the production department of the information obtained by quality control studies will assist in producing a quality product. The very fact that you install a system for quality control may, by its psychological effect, give a temporary lift to your quality. However, unless you follow through and take action when the ratings show that action should be taken, you will soon find that you are worse off with the system than you were without it.

Presented at the Southeastern Section of TAPPI, Charleston, S. C., Sept. 25–26, 1959.

Ohio (Indiana District)

The first meeting of the 1959–60 year of Indiana District, TAPPI, was held at the Marott Hotel on Sept. 15, 1959. The speaker for the session was John Swanson, of The Institute of Paper Chemistry. After the summer hiatus the Indiana District-Ohio Section began its third year of presenting interesting programs and meetings to its members. An excellent group of programs and meetings have been arranged for the coming year of 1959–60. Mr. Swanson led off with an interesting and informative discussion of "Fiber-to-Fiber Bonding." His address was illustrated with slides and proved very stimulating to those present. A question-and-answer session followed Mr. Swanson's presentation of the paper which is to be published in *Tappi* in the near future. The meeting was preceded by a social hour and dinner, and was presided over by the newly installed officers for the 1959–60 year, Charles Eberly, of the Paper Art Co., chairman. The programs for the year are being arranged by the vice-chairman for programming, Doyle Boggess, of The Beveridge Paper Co., assisted by his committee.

On October 20 one of the highlight meetings of the year was held in Crawfordsville, Ind. A mill tour of the R. R. Donnelly & Sons Co.'s outstanding printing and bindery plant was conducted from 1 to 4 p.m. with quided tours by members of the Donnelly organization escorting groups of three or four visitors. The tour covered every phase of the operations in this plant from printing plate preparation on through to the complete binding of the book. The plant is one of the largest edition binderies in the United States, and produces millions of books each year. Members of the Indiana District were highly impressed with the operations, and the excellent opportunity to visit this outstanding plant. A social hour from 5 to 6 p.m. followed the tour at the Crawfordsville Post of the American Legion. The chairman of arrangements for the day's activities was Frank Sulc of the Donnelly Crawfordsville Division Research Department. Dinner was served at 6:30 p.m. to over 50 members and guests.

Alex Glassman of the R. R. Donnelly & Sons Chicago Research Division presented a very outstanding paper on "The Print Testing by I. G. T. Techniques." The I. G. T. Print Tester developed by the Institute of Graphic Technology at Amsterdam, Netherlands, is the instrument used for this series of investigations and techniques developed by the Donnelly Research Department under the direction of Mr. Glassman. The I. G. T. Print Tester is used to evaluate pulp and papermaking in terms of consumer end-use requirements, and the paper described the four principal methods found useful in the prediction of production performance and final quality. Mr. Glassman stated: "The I. G. T. Print Tester is particularly valuable in predicting the paper-ink relationships because this machine provides; and accurate ink film thickness, available over a wide range; accurately controlled pressure available over a fairly wide range; testing apparatus that is quick and requires no craft skill; a continuous scale where constant acceleration takes place, as for pick tests." Mr. Glassman's discussion of this paper was illustrated with slides, and a very informative question-and-answer session followed at the conclusion of his presentation. This paper was first given at the TAPPI Testing Conference in Portland Ore. last August. Publication of the paper will be made in *Tappi* at some time in the near future.

The next meeting of the Indiana District-Ohio Section will be December 15 in the Marott Hotel at 6 p.m. Members of other Sections or National TAPPI members who find themselves in the Indiana area on this date are cordially invited to attend this meeting.

Cushing Roth, *Secretary*

Empire State (Eastern District)

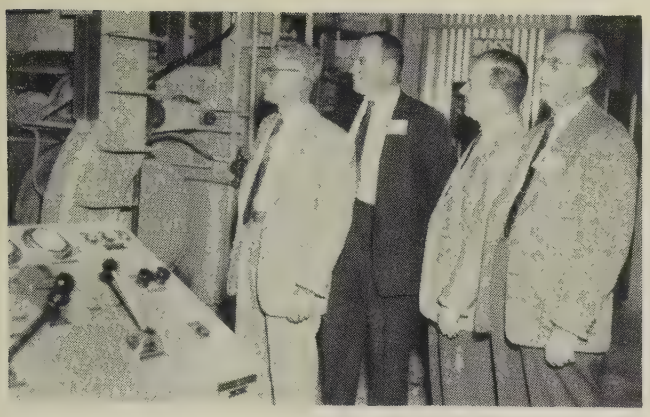
The October meeting of the Eastern District of Empire State TAPPI, features an afternoon tour of the International Paper Co.'s new no. 11 fourdrinier paper machine. Capable of speeds up to 2300 ft. per min., it has the finest facilities for machine coated papers.

The mill tour was attended by approximately 50 people.

The evening session was conducted at the Queensbury Hotel with 63 members and guests present.

The meeting was called to order at 8 p.m. by Chairman Paul Page. The officers for the 1959–60 year were introduced. They are as follows:

Chairman: Paul L. Page, Imperial Color, Chemical & Paper Co., Glens Falls, N. Y.
Vice-Chairman: Gordon Nicholson, West Va. Pulp & Paper Co., Mechanicville, N. Y.
Program: Gordon Rabeler, International Paper Co., Glens Falls, N. Y.
Secretary: Vincent W. Potts, American Cyanamid Co., Glens Falls, N. Y.
Treasurer: William Montgomery, Finch, Pruyn & Co., Glens Falls, N. Y.
Publicity: John McCoy, Finch, Pruyn & Co., Glens Falls, N. Y.
Asst. Publicity: Grant Ranscher, International Paper Co., Glens Falls, N. Y.



Members of the Eastern Section of TAPPI touring International Paper Co.'s Hudson River Mill at Corinth. Shown watching the operation of the mill's no. 11 new paper machine are, left to right: Gordon E. Rabeler, Glens Falls; Jud Hannigan, Hudson River Mill; Paul L. Page, Imperial Color, Chemical and Paper Co., Glens Falls; and D. C. Lincoln, International Paper Co.

Junior Awards: Harold Lake, Ciba Co. Inc., Lake George, N. Y.

Education: James Fusco, Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

Entertainment: John Williams, Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

The treasurers report was given by William Montgomery and showed a balance of $675.99.

Grant Cole has formed a "Raw Material Source List" whereby mills in the area would list chemicals and various other raw materials on hand at their respective mills which would be supplied in an emergency to any area mill upon request. Twenty mills have been asked to participate, 12 have not been heard from. This list of raw materials will be sent out to the Purchasing Agents in the various mills.

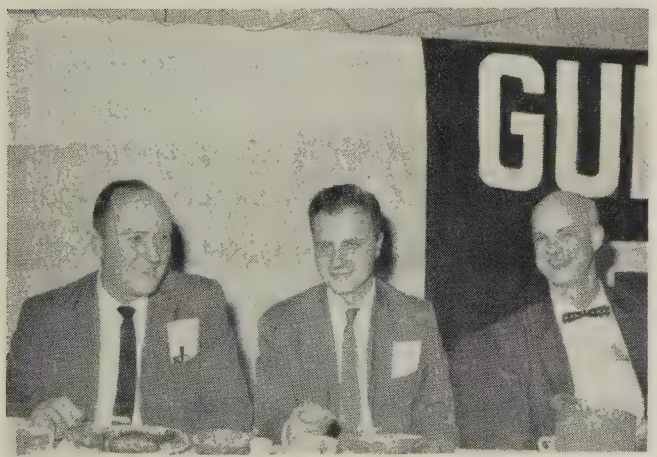
The Empire State 3rd vice-president Carl Johnson, was introduced and recognized.

The main speaker of the evening, Judson Hannigan, Jr., Assistant Manager of the Hudson River Mill of International Paper Co., was introduced by Gordon Rabeler.

Mr. Hannigan continued the theme of the meeting with "An Account of the Start-up of No. 11 Machine," in which he discussed its installation, start-up and operation.

A discussion period followed after which the meeting was adjourned.

V. W. Potts, *Secretary*



Omega Rodgers, Container Corp. of America; Cy Brady, program chairman; N. M. Le Maistre, Container Corp. of America

William Elsevier, International Paper Co.

Gulf Coast

The first meeting of the Gulf Coast Section of TAPPI was held Oct. 2, 1959, at the San Carlos Hotel in Pensacola, Fla. Total attendance was 85. Roy L. Miller was chairman of local arrangements, and Cy Brady was program chairman.

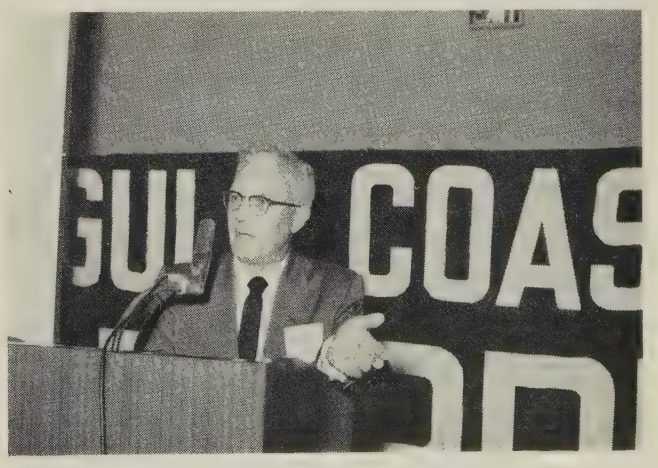
William Elsevier, chairman of the Section, presided at the meeting. The first speaker was introduced by Ion Walker of International Paper Co.

Omega Rodgers, paper mill superintendent, at the Brewton, Ala., mill of Container Corporation of America, was the first speaker. His subject was "The Rotabelt."

Mr. Rodgers described with the aid of slides, experiences in the operation of the Rotabelt at the Brewton Mill.

Unusually long wire-life has been one major result from the use of the Rotabelt. One wire lasted 85 days and three wires lasted 75 days each. Only 13 wires have been used since the mill started up in December, 1957. During this time only one hole has been sewed in a wire. Part of the credit for the long wire life is no doubt also due to the unusually clean pulp supplied to the machine. A Bauer Centri-Cleaner system (primary, secondary, and tertiary) is used in conjunction with a deculator. No sand holes have ever been noted in the Brewton sheet. Machine operating speeds to date have ranged from 230 to 700 f.p.m. The first Rotabelt installed on machine lasted 14 months. The belt can be changed on the run on a free stock or pulp.

The Rotabelt is not driven, but is pulled by the wire. It is most important that the belt be lined up squarely with the couch roll. No trouble with streaking is experienced if the belt is lined up properly. A 20 to 25 in. vacuum on the Rotabelt system removes all water passing the dandy roll. A 1 in. vacuum is carried on the last flat box before the Rotabelt.



Don Walker, International Paper Co.

Professor Cranston Jordan, Pensacola Junior College

No separator is needed on the couch. The Rotabelt system includes a 700 g.p.m. at 260 ft. head pump with a 6 in. suction. The pump usually operates at full capacity. Any overload noted on the Rotabelt is corrected by increasing the load on the wet boxes before the dandy roll.

The only difficulty noted in the Rotabelt to date was in starting it up synchronously with the machine. An air motor system is now used to start up the rotabelt in synchronous speed with the wire. The Rotabelt is the last point of contact for the wire as it passes to the couch. No trouble has ever been experienced at Brewton with wrecked wires.

The second speaker of the evening was Professor Cranston Jordan, of the Physics and Mathematics Department at Pensacola Junior College. His subject was "Evolutionary Operation—A New Technical Tool."

Professor Jordan's talk was an interesting discussion of experiences with statistical studies of typical paper mill operations. He used several slides in presenting the test data under study.

A brief summary of points of interest includes the following:

Experimental data can be built up to advantage by studies within the control limits of a process in normal operation. The factors under study should be those which have major influences on character of product. Uncontrolled major influences will tend to obscure the relationships under study. Monthly averages are not always an advantage. Long range influences will interfere. Seasonal changes, raw material quality variation, necessary adjustments in operation control settings, and other things tend to confuse the picture on extended studies. Generally, it is better to procure experimental data over a short enough period of time to avoid long term fluctuations.

The Pensacola meeting was concluded Saturday morning with a visit to the woodlands of St. Regis Paper Co.

N. M. LeMaistre, *Secretary*

New England

The Fall Meeting of the New England Section of TAPPI was held jointly with the Connecticut Valley Section of PIMA at the Berkshire Inn, Great Barrington, Mass., on Oct. 2 and 3, 1959. There were 281 members and guests on Friday, October 2 and 276 on Saturday, October 3.

Five technical papers were read:

October 2, Friday, "The Color Magician," O. C. Holland, Director of Advertising, Interchemical Corp., Printing Ink Division, New York, N. Y.

Printing Session

October 3, Saturday A.M., "Printing Problems on Paper," W. M. Delbrouck, Technical Consultant, Union Bag-Camp Corp., Savannah, Ga., "Some Problems in Printing Boxboard," James Wing, Printing Research Group Leader, Continental Can Co., Boxboard and Folding Carton Division, Uncasville, Conn.

Equipment Session

October 3, "The Selectifier Screen," Arthur Sternby, Black-Clawson Co., Middletown, Ohio; "The Story of the Bird Centriscreen," Mr. John Colran, Bird Machine Co., East Walpole, Mass.

John Lewis, *Chairman*

Printing Problems on Paper

W. M. Delbrouck

Printing problems on paper is a topic which can be discussed at great length from hundreds of angles by the paper maker, the converter, and the printer. But, since the printer is the man faced with processing the finished product of the paper mill, let us look at some of the things he expects and some of the things he would like to have in the paper he buys from the mills.

To the printer, paper is something on which he must apply layers of ink. He must wet it, dry it, heat it, and cool it while putting on the ink. He must cut it, square it, and fold it. In many cases, after printing and folding he has to trim the edges, paste it, perforate it, and put stitching wire in it. In other words, he just plain beats hell out of it. And sometimes the finished jobs show it.

First he expects all of the paper to have the same quality. He wants uniformity in surface finish, whiteness, and color. He expects smoothness, cleanliness, brightness, and the ability to reflect light in the case of coated papers. He expects the surface finishing to be the same on both sides of the sheet whether it is roll or flat stock.

Coupled with a uniform surface finish he expects uniform surface strength; resistance to picking, to linting, and fuzzing. The surface must withstand breaking over feed rollers, gripper fingers, tapes on folders, clamps on binders, and so on.

The next characteristic in the appearance group is receptivity to ink. Because if the paper does not take ink properly it does not dry well and is subject to marking, rubbing, and offsetting during the printing and binding processes.

Usually when a press run is started the amount of impression is set to suit the surface and finish of the paper and the ink is applied in just the right amount to get the color shades desired. The ink is adjusted to suit the surface strength of the paper and every consideration is given to drying.

If there is a variation in surface brightness or color of the paper, or the coating is uneven, the ink color begins to alter. Not very much on each color but on the four colors in combination, the job can vary in shade perceptibly. If the coating varies in depth it appears as though either too much ink has been applied or too little. In the areas where it appears as though too much ink had been applied the highlight dot screens appear to spread and the image takes on a cloudy effect. If it appears that there is too little ink there will be a breakaway of the dot pattern and the dots gray out to disappear. In either case, the quality of the job varies and the smoothness of the ink layer is lost.

When a good pressman sees this variation on his printed job he can compromise to a certain degree but a continuous variation in the paper coating or surface means continuous changes and adjustments to finish a job which will be delivered below the expected quality standard.

Paper with a uniform finish and surface will make the pressman's job much easier regardless of the printing process involved. One of the most upsetting things a good pressman faces today is to find that he has done an excellent job of printing on one side of a piece of paper and then when he goes to back it up, he finds that the surface on the backside is slightly different and he does not get quite the same color tone.

W. M. Delbrouck, Union Bag-Camp Corp., Savannah, Ga.

In the case of a publication, when the paper is folded and facing pages which are run on two sides of the sheet are opened, they appear to be in a different color.

Another problem which faces the printer today is caused by multiple sheeting of rolls at the mill. If one of the rolls is below standard or does not meet the specifications for caliper, finish, shade, or opacity, it means that one sheet in each cutter set will give him a variation in his job. Since it is practically impossible to pull these sheets out of the pile about all the pressman can do is adjust his makeready and inking to suit the poor sheet in the sequence. To do this, he may have too much or too little ink on the rest of the sheets, so that the poor sheet really controls the press condition and the better sheets of paper will show poorer actual printing.

FUNCTIONAL REQUIREMENTS

The next group of paper characteristics can be called functional requirements for they are the built-in qualities of the paper, not the surface. They include thickness, bulk and weight, formation, opacity, strength, and folding and creasing qualities. Variations of these characteristics affect running speeds and production on presses, folders, and bindery equipment.

There is another functional quality which has developed more noticeably since press speeds have increased. All of us, in the paper business, are becoming increasingly aware of the paper conditions referred to as "compressibility." Compressibility is the ability of a paper to squeeze together under the impression of the printing plates, and to recover when the pressure is relieved. If the paper is resilient, it will not show excessive printing pressure through the pages.

Opacity is a most important functional requirement. When the printer applies ink on paper he attempts to get as much color strength as he can with a minimum amount of show-through on the back. Variations in thickness or formation of a sheet of paper affect its opacity and thereby vary the amount of show-through which is evident. Show-through is color strength showing through a sheet, while strike-through is excessive ink penetration on a thin sheet which shows on the reverse side.

When printing is done on web presses by any process, all the rolls should have the same tension strength, that means at both ends and in the middle. If there is a variation in tension, the web has a tendency to wander and this affects side register. If the center of the roll is slack, creases and corrugations occur. If any of these faults are very bad, they usually cause breaks in the web.

Much of the modern, high-speed web equipment is fitted with electronic control to help correct and detect some of these conditions, but they cannot cope with all the minor variations in tension and the defects such as slime spots, holes and foreign matter wound up in the rolls. Unmarked splices, or breaks are a couple of other things which could be included in this little category.

Offset paper has different hazards. It must be uniform in strength so that it can overcome the tension created when the paper is peeled off the blanket on a heavily inked form. Foreign matter and ream markers left in the middle of the pile are still serious hazards in this process and nothing yet known makes them compatible to the press blanket.

The need for careful trimming, sorting, inspection, packing, counting, and shipping is the universal cry of the printer. He wants square stock with clean edges, no fuzz, no lint, and no break-off. Squareness is important to register on the printing press but it is also important when the paper is processed over a folding machine. The ends of the paper (side guides on a printing press) become the in-feed edges on folding machines and any variation is doubled at each right angle fold. Printers want sheets squared up two sides for work and turn forms, and squared four sides for tumble sheet forms. Any variation from squareness of course affects quality.

I have refrained from saying anything about moisture content in the paper although it is one of the biggest headaches in the pressroom. The printer does want a reasonable amount of moisture in the paper, enough to give it dimensional stability to a certain extent, but the trouble is that there are not many different interpretations of what constitutes reasonable moisture content and what constitutes an ideal running condition in a plant that there just isn't enough time to go into it in detail. Certainly, paper mills are taking the precaution of maintaining what they consider a sufficient amount of moisture in the paper, by wrapping skids, rolls and packages in moisture barrier wraps and they find it difficult to assume responsibility for stretch and curl after the paper has left their shipping docks.

Experience has indicated to us that plants operating in a relative humidity range of about 40 to 45% for 72°F. experience less overall difficulty in processing papers and maintaining press register than those operating in higher or lower humidity-temperature ranges.

If all of these wants and desires of the printing trade could be summed up in one word, I believe it would be "uniformity." However, let us take a look at a job of printing through the eyes of a paper mill. Those of us who are affiliated with the phase of the paper industry which makes papers that are to be printed, know that many things happen to interrupt production on printing equipment—and when there is an interruption in press production the first thing that is affected is the pressman's disposition and the second, is the printer's profit on the job. We know that when a man's disposition is affected, his irritation can be soothed with a sincere demonstration of desire to be of assistance, but when profit or the man's pocketbook is involved he can become downright emotional and unreasonable.

However, most of us have been exposed to discussions of complaints and problems affecting the processing and printability of paper. These include all of the things mentioned earlier along with a few others of a more spectacular nature. But I would like to devote the next few minutes to a discussion based on the mechanics of printing on papers of standard quality.

We, in the papermaking industry, must have a broad understanding of the business for which we supply the raw material. This better understanding enables us to appreciate the many factors involved in producing a piece of printing and it also aids us in determining to a greater degree our responsibility for making adjustments for alleged quality defects.

Even when press production is good the printing quality result can be disappointing to the customers; and as mentioned earlier in such cases, the printer is faced with a loss of prestige, a possible adjustment on the selling price of the job, and even a possible loss of the customer. It has been my experience as a mill representative that each of these things or a combination of all of the circumstances usually results in a complaint or at least an expression of doubt about the quality of the paper which was delivered for the job.

It has been indicated by some unknown authority who did an extensive analysis on a variety of printed specimens, that most production difficulties and quality disappointments on printed jobs are rightly chargeable to the printer or lithographer—or to his customer. Some of the common causes indicated that photographs and art work supplied by the customer were not adequate to deliver the result expected. The paper chosen by the customer for the printed job was not suitable for the work; the printer or lithographer had tried to affect economies by cutting corners; or there were indications of negligence or carelessness which perhaps could have been attributed to a low price.

Any kind of a photograph can be reproduced faithfully by one or another of the graphic arts processes if no limitations are imposed on the method, the selection of materials, and the cost. But practicalities impose limitation.

Impracticalities, too, impose limitations. Often, buyers of printing expect crisp contrast and sparkle in reproductions

from photographs that lack sparkle and contrasting tones. When photographs lack desired tone values, the pressman cannot create them. A skilled pressman can print only the values that are in the plates. Efforts to "boost" the plates cause other faults and other production difficulties.

Yet, when printed reproductions fall short of a customer's expectations he is disposed to charge his diappointment to the lack of skill or to the negligence of the printer. Recriminations follow. Somebody or something in the production sequence fails: Was it the platemaker, the pressman, the ink, or the paper?

An atmosphere of disappointment is a poor environment for explanation of the true fact that the desired values were not present in the photographic copy; or of the fact that the customer had been unwilling to pay the cost for making compensations for the presence of screen in the plates. In an atmosphere of disappointment, such true explanations are regarded as alibis and are likely to deter further relationships. The potentials of the graphic arts processes can be capitalized only when the customer cooperates with a processer in the planning stage. The quality of half tone prints is not determined in the pressroom.

Photographs that lack shadows will also lack highlights. They cannot properly be expected to acquire sparkle on the press; they will produce flat drab reproductions. Photographs that contain dense black tones and crisp highlights cannot be expected to print equally dense and crisp unless they are subjected to special treatment. The introduction of a screen is essential for printing. However, the screen will dilute the density of the solid blacks and the brilliance of the highlights. Many photographic subjects are so composed that a platemaker can take the screen out of the solids and the highlights for a only a slight additional cost.

It is not always possible for a skilled buyer of printing to get photographs that are ideal for reproduction, and sometimes he has to do the best with what is available. However, if he gets a majority of good illustrations he can suffer a few poor ones and, of course, there are other buyers of printing who are not quite as familiar with the process as they should be; or who haven't the courage to demand good photo copy or they do not have the money to pay for it. Then, too, we must consider that not all printers are skilled and experienced in the methods of getting quality printing.

When plates made from inferior illustrations go to the press, things usually begin to happen. The printer and the lithographer know that the customer is not going to be particularly happy because the illustrations are without punch—there is no contrast. After a look at the first running proof of the job, the boss tells the pressman to wash up and try another ink. This doesn't seem to satisfy, so the boss says "Well open up the fountain a couple of notches and see if that won't help it." This is known as forcing the plate.

The idea is to try to force the plates to print a black that isn't there by using an excessive amount of ink. The result is that the black tones get mottled, the lighter tones are filled up, and all other halftones in the same inking channel are adversely affected and contribute to the same general mess.

To overcome the excessive amount of ink, the pressman increases the amount of offset spray deposited on each printed sheet to prevent set-off. This just adds to his troubles and makes him stop at intervals to wash up. Occasionally, if the ink coverage on the paper is heavy enough, an excessive amount of spray may cake on the surface and cause sheets to stick together. But the real trouble comes when the lifts are turned over so that the paper may be printed on the reverse side. The excess spray is then deposited on the unprinted side and as it goes through the press again it is delivered with an artistic assortment of hundreds of white specs.

At this point press stops and wash-ups are frequent and cause the press time to exceed the estimate. The ink cost also exceeds the estimate and the results obtained on printing the first side are poor while the illustrations printed on the reverse side are poor with an extra bonus of millions of white specs.

This is where we come in. Expressions of contempt and lack of intelligence are rained on the paper mill, its founders, and their ancestors. The paper is the lousiest lot that was ever delivered and we should assume the responsibility of paying for excess press time, extra cost of ink, and making further cash adjustment to compensate for the discount which the printer will surely have to offer the customer to take the job off his hands. The source of the printing trouble is evident. The artist, photographer, and the plate maker could have precluded the trouble for much less cost. The printer would have added to his prestige, and the customer would have been happier had the job been planned.

I hope that these few remarks have emphasized to you the feeling of the printer for greater uniformity in all aspects of the product we give him so that he has every opportunity to demonstrate his skill. Also, that the need for a better understanding of the printing processes and many requirements be accelerated so that the printer's raw material, paper, can be more scientifically adapted to meet these requirements.

Presented at the Maine-New Hampshire Section of TAPPI, Great Barrington, Mass., Oct.2–3, 1959.

The Story of the Bird Centriscreen

John Cloran

THE purpose of this brief paper is to bring you up to date on the latest development in the screening of paper stock. I know that some of you have already acquired the intimate knowledge of this newest screen that one gets from daily use but even its users may find something of interest in the story of the Centriscreen's development and operation, for, unlike many of the screens of earlier design and application, this one is totally enclosed so that you cannot see just what it is doing and how it works just by looking at it.

Before I take you inside the Centriscreen, however, let me tell you a little bit about how it came into being in the first place. I think I hardly need to remind you that my company, Bird Machine Co., has been a leading factor in the pulp and

JOHN CLORAN, Bird Machine Co., East Walpole, Mass.

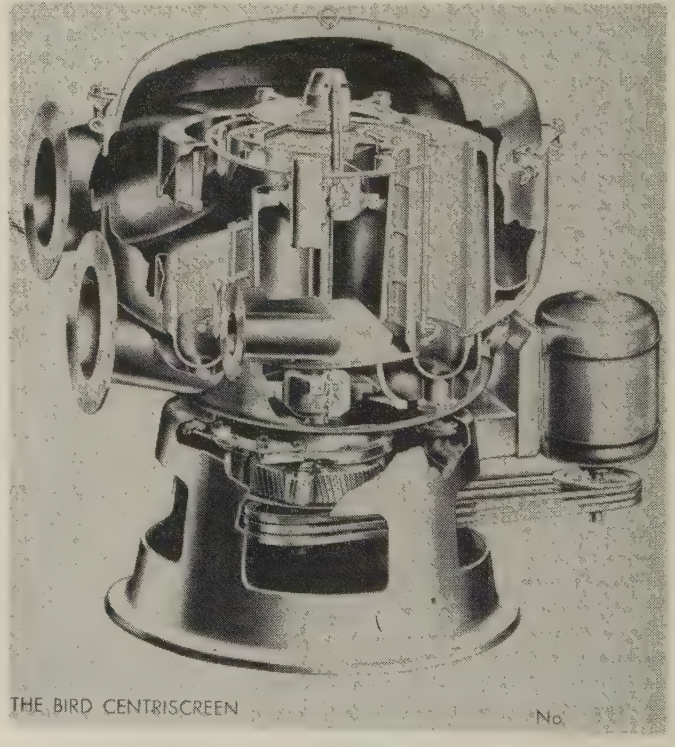


Fig. 1 Cutaway view of Model 14 Centriscreen

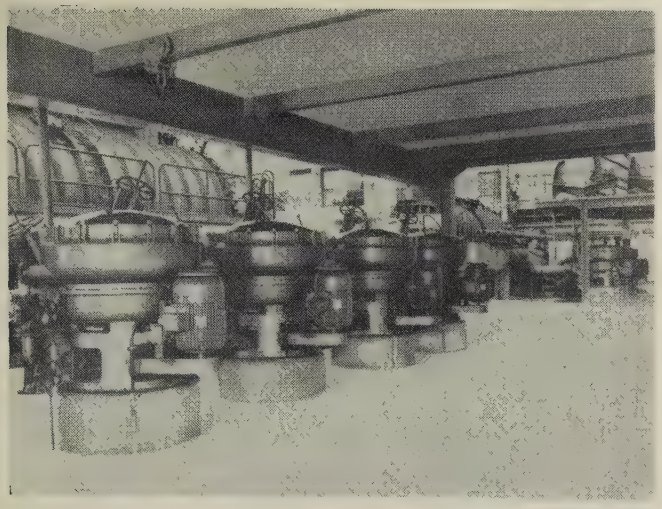


Fig. 2

paper screen business for a great many years. Our experience in screening dates back half a century with the development of the Bird rotary screens when continuous production of uniformly good paper was just coming into its own. Since then there have been numerous developments not only in screening but in other methods of removing foreign matter, that is, shives and dirt from pulp and paper stock. If qualification for the design and development of this latest type of screen is needed, I have only to mention such preceding Bird Machine developments as the big 3A Bird screens, the Bird Jonsson screen, the Bird Vibrotor screen, the Bird Centrifiner, Dirtecs and Cycleans—all widely and successfully used throughout the industry.

With all these methods and equipment, why still another type of screen and why has it received such widespread attention and immediate acceptance? The answer lies, of course, in the evolution of the industry and its efforts to keep pace with the extraordinary demands for its products. As paper machines run faster an uninterrupted flow of clean, uniform stock becomes a virtual necessity, and it is necessary to resort to delivery of the stock through enclosed head boxes operating under pressure. This in turn meant totally enclosed screening with screens delivering the stock to the head box at the desired pressure. The need was acute not only here but in the big Canadian newsprint mills so it was natural that the engineers of the leading builder of screening equipment here should team up with those of the leading screen builder in Canada, Canadian Ingersoll-Rand Co., Ltd., to develop a screen meeting these new and drastic requirements. After several years of intensive effort in research and development and engineering study with literally thousands of tests under actual field conditions, the Bird Centriscreen was the outcome. Its purpose was to combine high screening efficiency, large capacity, low power input, mechanical dependability and freedom from screen plate troubles and breakage in a compact unit that would be easy to install, operate, and maintain. How well it has succeeded is already a matter of history as will be evidenced by the pictures of representative installations that I will show you.

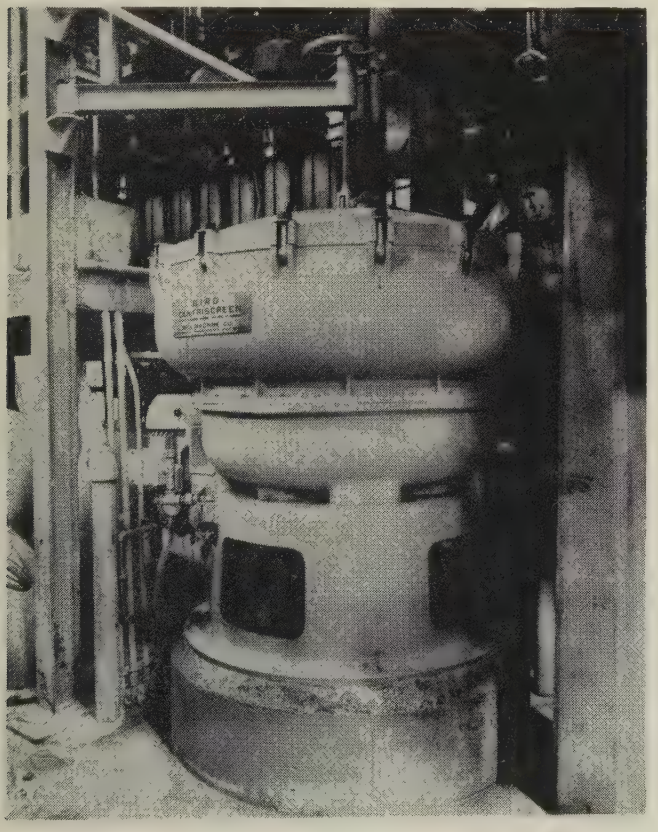


Fig. 3

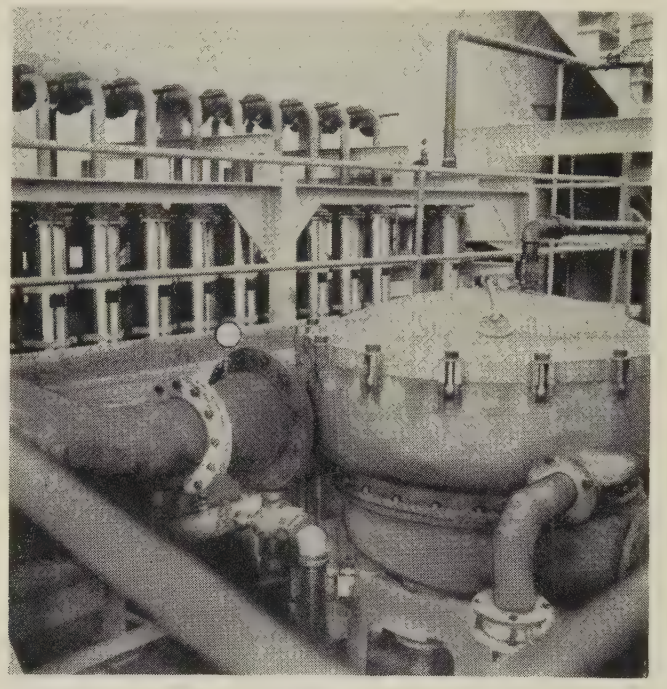


Fig. 4

But, first, I would like to take you inside this well covered up machine so you can see for yourself just how it does the job. Figure 1 in a cutaway view of the Model 14 Centriscreen. The stock enters the 14-in. diam. inlet and flows tangentially into a chamber or trough that runs around the entire circumference. A tangential trap located in this chamber catches and removes large and heavy objects before they can do any damage to the screen plates.

The stock flows over and down into an annular area between two concentric screen cylinders. Accepted fibers pass through each respective screen plate and the flow of clean stock passes to a common outlet. The rejected shives and dirt particles flow downward between the two screen cylinders for collection and removal.

A set of rotating foils, two to each screen cylinder, sweeps through the screening area causing momentary back flushing through the screen openings to keep them constantly open and clean.

The flow of both stock and tailings is precisely controlled to assure minimum passage of good fibers into the tailings which are of high consistency and reject content.

There are construction features that need only be mentioned in passing. The rotating assembly in the screening chamber is

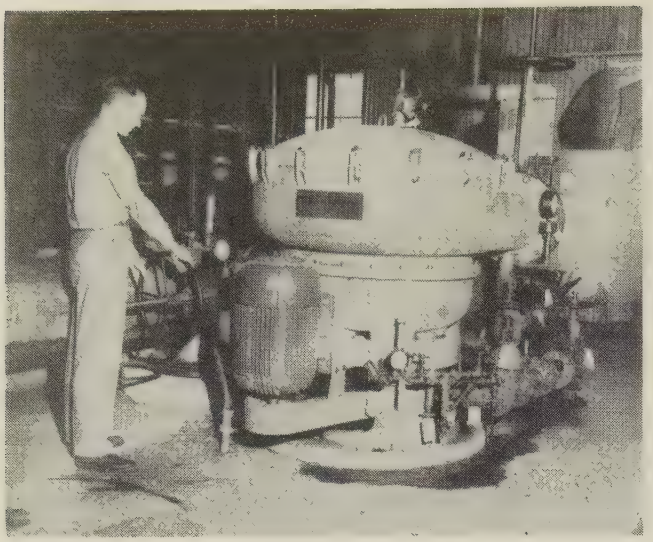


Fig. 5

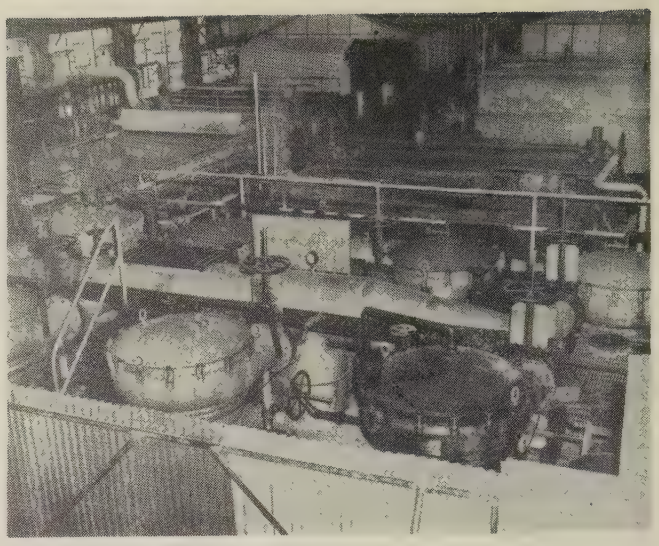


Fig. 7

held fast by a rigid squirrel cage design held securely by a top and bottom ring. A drive hub and spider support this rotating assembly on the screen shaft. The foils are the only rotating parts of the Centriscreen and the shaft is supported by oversize spherical roller bearings outside the screen casing so they are kept dry and clean. The Centriscreen is built to operate at pressures up to 75 p.s.i. All parts in contact with the stock are of no. 316 stainless steel. Cast steel with interior coating and bronze are available if required. The case is so designed that the inlet and outlet may be located at almost any desired position around the circumference.

As to capacity, feeds in excess of 5600 g.p.m. are capable of being handled by the Model 14 Centriscreen, maximum capacity depending on the character and consistency of the stock. Yet the screen occupies only a 6 ft. circle of floor space. Figure 1 shows a cutaway view.

Figure 2 is a handsome installation of seven Centriscreens at The Great Lakes Paper Co., Ltd., Fort William, Ont. The four in the foreground are on no. 4 paper machine, 342-in. "Jupiter," the world's widest paper machine, rated at 425 tons per day at the reel. The three, right rear, are on no. 3, 272-in. "Jill" rated at 300 tons per day. The mill reports quality of newsprint is excellent and holes in the sheet, formerly troublesome, have completely disappeared, as have costly breaks due to dirt.

Figure 3 is the Centriscreen installation at Crown Zellerbach's Camas mill making breadwrap and lightweight specialties; it shows how little space is required. Wire life has materially increased due to elimination of grit. Lumps used to streak the sheet, but no more.

This Centriscreen shown in Fig. 4 is at Crocker-Burbank on their rebuilt no. 5 machine. It is accompanied by a battery of Bird Cycleans, the combination resulting in a cleaner sheet and reduced rejects.

Figure 5 is a Centriscreen on neutral sulphite stock at Sonoco Products Co., Hartsville, S. C. You can see what a neat, compact installation it makes. It delivers 170 tons per day of clean stock.

Figure 6, taken in our shop, shows the relative size of the Model 10 and the Model 14 Centriscreen. The Model 10 has approximately half the capacity of the Model 14. It is ideally suited for smaller fourdriniers and for cylinder machines requiring one screen per mould.

The nine Centriscreens shown in Fig. 7 are on the job at International Paper Co.'s Springfield, La., mill making kraft on a high-speed machine.

The Centriscreen in Fig. 8 is at Green Bay Pulp & Paper Co., Green Bay, Wis., delivering 235 tons of semichemical per day. One of our good customers looked at this picture and said, "Why did you have that operator posed with his hand on a

Fig. 6

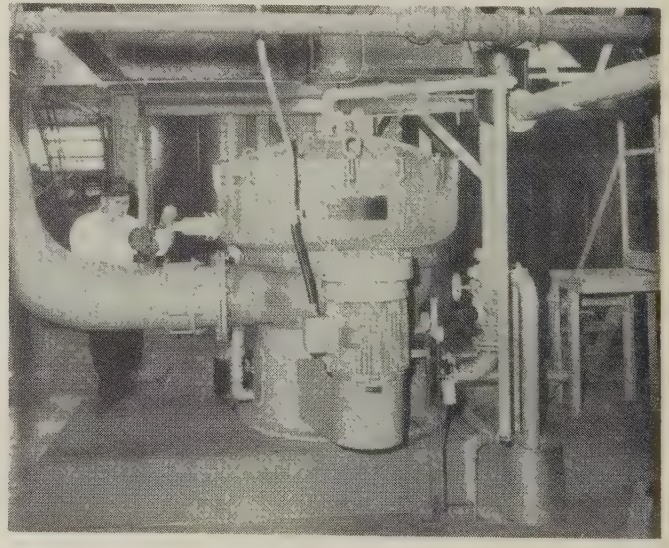


Fig. 8

valve? You might give the impression that the Centriscreen needs operating attention when actually all anyone has to do is start it up and let it run. That is why it's so popular with the machine tenders and maintenance crew."

I guess this is a good note on which to end my remarks.

It has certainly been a pleasure to be given this opportunity to tell you about this latest screening development and I appreciate and thank you for your courteous attention. Now, I am going to ask you to take it from here. What questions do you have—what more would you like to know about the application of the Bird Centriscreen? If I cannot give you a satisfactory answer, perhaps one of my associates here can. At any rate, we are willing to try.

Presented at the New England Section of TAPPI, Great Barrington, Mass., Oct. 2–3, 1959.

Automation and Management Controls

William Alden

All plants are becoming more integrated as they move toward the automatic factory and thus the procedures and instruments that are used to control product quality are married to the methods and figures used to control costs and customer service.

Let us look at the different methods of controlling costs. In the early days of business a man judged his prosperity or profitability only by the amount of gold, property, or cash that he had accumulated. In those times a merchant or tradesman operated out of his home or a small shop with inexpensive tools. He bought, made, or converted, and sold material in a relatively short period of time—in fact usually against a definite order. As larger buildings, inventories, and more expensive equipment were required, however, there were such costs as replacement costs that did not show up immediately. Thus depreciation and other "book" entries had to be accounted for. It became necessary to figure profit on a bookkeeping basis, just to make sure that this accumulation of wealth, though postponed, was eventual. The manager wanted to know sooner whether he was accumulating or losing wealth and hence demanded an accounting more frequently, because all expenses would not show their effect on cash soon enough.

Here is a chart (Fig. 1) which shows the usual relation of costs, sales, and profit in a business. At the bottom we have fixed costs which in one company are general taxes, general insurance, building repairs, depreciation, obsolescence of equipment, superintendence, minimum budget for foremanship, administrative expense and selling expense. On top of these basic costs we have some variable overhead expense of semifixed costs—indirect shop labor, drafting and engineering labor, time keeping, cost department and payroll labor, depreciation of equipment, compensation insurance, social security taxes, foremen, departmental supplies. Then we might have a repeat of some of the headings listed under fixed overhead costs. To this is added the variable cost to make the total cost curve. Variable costs would be material, interest on stored material, and labor. The dotted line represents sales which is equal to the unit price times the units produced. The difference between sales and total costs is loss or profit.

This single end profit figure and the return on investment for the whole plant were the only figures the president would need to get an idea of the effectiveness of the total effort of his firm. But as mass-production grew and the number of people in a company grew and the president no longer had close touch with the front lines, and the list of costs and expenses multiplied and profits narrowed, it became necessary for the president, or his executives, to know in greater detail and more immediately, the source of excessive costs

William Alden, President, Automation Management, Inc., Westboro, Mass.

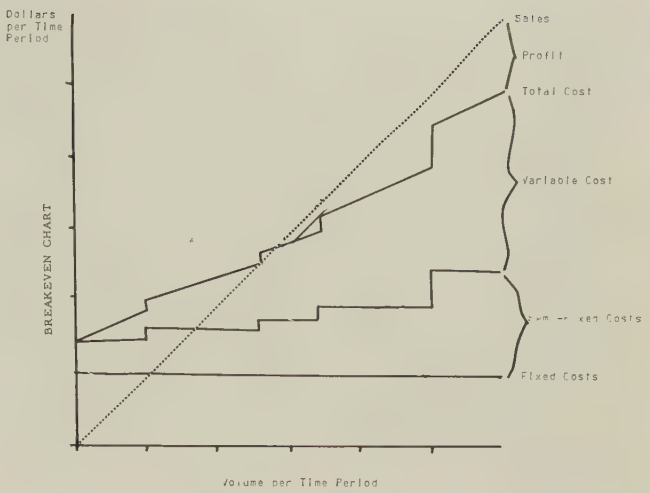


Fig. 1. Breakeven chart

and above normal profits for lowering costs and operating the most profitable lines wherever possible.

Therefore this same type of analysis as on this chart is now applied to individual departments or to production runs within these departments.

There are the fixed costs of heart, light, maintenance, and depreciation of machines and buildings and so on, as listed earlier. The total company fixed cost is usually apportioned to a department on the basis of square footage or some other governing factor.

Then there are the set-up costs which remain the same regardless of the length of run.

There may be some costs which remained fixed until a certain volume is attained. For instance, a definite number of men may work below or at capacity and when the volume goes beyond their capacity an extra man is added and thus there is a jump in costs, without a parallel jump in volume produced as shown in Fig. 1.

After a machine runs for a certain period the product may move outside its tolerances and thus require adjustment of the machine, which of course again causes a jump in the semifixed costs. In addition there are the directly variable costs of labor and material.

Just as the selling price sets a standard within which the president must operate his company, so these curves when derived for a department or production run of each type of paper set a department standard which foremen in most of the departments must meet if the whole company is to make a profit. If a foreman has a cost above the standard cost line then he would have to explain why and likewise if it was beneath it he would try to see if the favorable conditions could be repeated on future runs of that particular product. And thus managers have found it most profitable to devise standards for the amount of labor and material to be used with a certain formula or production run.

You may be familiar with the article entitled "Using Data Reduction for Continuous Processes," by W. E. Chope (*1*). His subdivisions within the broad categories of labor and material are, in dollars, raw material cost, fresh water, steam cost, wet broke, dry broke, downtime, labor and overhead, to make a total of the manufacturing cost. Against this he has in dollars the amount of production in tonnage out, reams out, moisture out, to credit the dollars against manufacturing costs. He compares the actual usage with the standard or goal.

In engineering these standards one would take into consideration what has happened historically on past production runs. But one would also make a detailed analysis to separate out what was standard procedure and what was not. Thus one might get into the use of time studies or MTM, that is, methods-time measurement or similar sys-

tems. You would also use *operations research* or the industrial application of the game theory, probability, waiting line, linear programming, and so on. Thus, included in this standard would be a certain time element allowed for breakdown, that the company necessarily has to expect on the basis of probability. A large airline used operations research on planning the maintenance of their planes and was able to free two planes for use, thus adding essentially two planes to their fleet for only the cost of the operations research analysis (*2*).

Simply to compare what was done "the last time" is not adequate. "Last time" undoubtedly had a different length of run and hence different costs. Certainly in an informal comparison one may not be comparing the run to one that had the same set of conditions. When historical standards are the only ones used, then one is providing a cellar for his operation and not a ceiling. In other words, the efforts of the workers will be to do as well as they have done before, but not to do as well as they can. However, often the cause of low productivity is not with the individual worker. In over 90% of the cases, the workers wish to put in a full day's work and they will do so if they have an adequate supply of proper quality work ahead of them. Often this is not the case due to poor training, motivating, or apportioning of the work by the supervisor, or an uneven flow of below quality product from one department into the next department which in turn can be blamed on the lack of tight centralized quality and production control.

If you have not already done so, you would find it interesting to set up a complete set of standards for as many of the variables as possible on certain production runs, either in the papermaking end of the plant or in the finishing end. Comparing these standards to actual results, you would undoubtedly find the means of correcting inefficiencies and desire to do the study on a regular basis. In fact, you may wish to make comparisons against standard as the run progresses, as we are proposing for the Post Office Department. In this way, costs can be controlled before they become excessive. In the post office work we also control the patron service during the run. Likewise you would be able to control quality through an instantaneous reporting system.

To correct a problem you must know its magnitude, cause, and the time that it occurred. Lacking this information management's conversations with the foremen will provide more heat than light. Without knowing the time you do not have a definite idea of what people were present and therefore responsible. It also might help in the analysis of the cause. Without knowing the cause it is impossible to avoid the same cause in the future. Without knowing the measurement of the problem one does not know how much effort in correcting it in the future is economically worth while. I have found that in most companies the people are well aware of the problems we point out to them. The only difference is that we assign a measurement to them so that they know which of the many problems they face should be worked on and with how large a budget.

The engineered standard is also useful in the sales department for pricing. It is very true that the sales department may say that small orders lead to large ones and therefore short runs will be tolerated. However, this setting of standards, getting these curves out into the open for a production run and type of paper, allows the president to decide intelligently if this policy is worth the extra cost.

Knowing costs, at least, on important runs, is helpful in planning production because these costs are needed in order to figure the best raw material inventory, finished goods inventory, and the proper sequencing of work through the plant. For instance, to find scientifically the minimum sum of storage and production costs we use in operations research a formula such as shown below. It is described in a paper by Robert Oliver, one of the operations research analysts we are using on our work for the Post Office (*3*).

The problem without inequality restrictions is to find a minimum to the sum of storage and production costs:

$$R = \lim_{T \to \infty} \left[R_{T+1} = \frac{1}{t+1} \sum_{t=0}^{T} (C_1 X_t^2 + C_2 Y_t^2) \right]$$

where

$X_{t+1} - X_t = \Delta X_t = Y_t - Z_t$
X_0 = fixed initial inventory.
C_1 = unit quadratic inventory cost.
C = unit quadratic production cost.
X_t = inventory level at beginning of period (t) and end of period ($t - 1$).
Y_t = production rate of period (t).
Z_t = sales rate of period (t).

You have often heard of people who boast of their low inventory. This is a "one-side-of-the-coin" measurement, however, in that what the inventory is not costing them in interest may be costing them much more in loss of sales and reordering costs. Thus operations research tries to balance the cost of having an inventory on hand against the costs that accrue for not having it on hand. Some of the costs of carrying an inventory are interest, taxes, insurance, storage, protection, obsolescence, deterioration, and other losses and specialized costs that vary in different firms. The costs of not having an inventory or having less of an inventory are the cost of running out of stock, the cost of shutdown and start-up, guaranteed pay, mechanical cost, unemployment compensation, public and employee relations. For instance, Eastman Kodak operates at a fixed production rate year round even though their sales are seasonal, not just because it makes sense costwise, but because it is worth something to them in the employee relations. Other factors are risk of loss of skilled people, cost of bumping, lost profit from canceled orders. Incidentally, in one study for a chocolate company, it was obvious that a box of chocolates not on the shelf of a store when asked for was definitely lost profit to the supplier because the customer in every case would buy an alternate box of chocolates, if the brand they first asked for was not there. Then there are the cost of back-order or other special procedure, customer relations, cost of expediting, cost of setup, cost of purchase, receipt and inspection of goods. A study using this analysis for a service parts company discovered that the largest return on their money could be obtained by putting their dollars into inventory. It is interesting to note in business history the increasingly sophisticated measures of success: gold, cash, net worth, and now such bookkeeping estimates as profit lost due to zero inventory.

Fortunately the collection of the data necessary for these tighter management controls can also be used for quality control by reporting as it happens the vast experiment that is occurring each time a production run of paper is made. Even though papermaking is still an art, it will not always be. Some bakers claimed this for their trade once, but now cookies are made completely automatically. If the important variables are known, measured, and properly interrelated we will be able to have much greater control over them and their final product. Certainly if science is making progress in mastering the variables of space flight, the paper industry will make similar strides in handling variables in papermaking. I believe you have already heard of the success of Rath & Strong in this area with a Midwest paper manufacturing company. As I understand it, they were able to cut the variability of production lots to 20% after having studied the effect of changing the main variables of papermaking in a controlled experiment during actual production. Incidentally, the manager of Alfax Paper & Engineering Co., a converter of electrosensitive paper, states that he might be willing to pay a premium price on paper that has, in each lot

received, the same qualities of wet strength, absorbency, amount of remaining chemicals, and permanency in storage.

In the previously mentioned article, Mr. Chope suggests a report form which could be read out of a proposed central control and logging system, hourly or on demand. The form would report water removed from the fourdrinier, press, and drier, the usage of fresh water and steam plus the felt condition. It would also show figures on the paper at the wet end, dry end and after calendering, down-time hours, area production reams, tonnage, basis weight, moisture, and formation. Goal figures and per cent of goal realized would be printed. I am sure that you would find these figures helpful in observing this chemical experiment of papermaking. Naturally you might wish to add some others such as temperature, flow rate, and so on.

We are working on a project designing a similar system for the United States Post Office where input, output, and inventory of mail, plus the man-hours required are measured automatically at each segment of the production process and reported instantaneously and visually on a panel. Mail volume would be compared to the standards for efficiency and patron service. Then corrective action would be taken on the basis of the decision rules derived from the operations research model.

As I first walked through the papermaking plants I expected to see a central control panel as in the refineries, chemical and cement plants, such as the Ideal Cement Co. picture in Fig. 2. Cause and effect on the whole process would be noted. For instance, it might allow such tighter use of facilities as the proper, instantaneous balance of the use of steam for heating and power and thus allow greater utilization of the steam. Here the measured input of material would be observed and perhaps controlled. It might measure the advantage of introducing scrap paper at a regular rate rather than in irregularly timed lumps. It is already agreed that this is a bad method, then the men dumping would be corrected when their inappropriate action was shown at the control center. The center would allow one to evaluate the feasibility of finer separations of the types of scrap used. Frequently, however, management is not willing to install an expensive data collection system with the hopes that it will simply produce better quality whose worth is difficult to measure. Fortunately, we have found in many cases our cost cutting work has in less than 3 years paid for the equipment and engineering which not only delivered the savings but also increased customer service and product quality. In cutting one crew of men in one operation from 24 to 11, or 55%, we reduced rework 44%. The savings paid for the whole project in 4 months. The reverse is true, too. In an effort to increase customer service, we not only accomplished over a 20% improvement here, but reduced labor cost by over 15%. In a very progressive instrument company we were able to increase production over 20% by installing a performance reporting system. Management has been aware of the various problems that the reporting system pinpointed. However, now that they knew that a shortage of parts had cost them some 30% in efficiency they found a net profit gain by adding an expediter to speed interdepartment delivery. Northrup Aircraft Co.'s performance and cost evaluation program has met with similar success.

In paper companies "lost time" standards will allow you to see what time was actually lost or if the time was necessary. You would be able to trace the causes of shrinkage. Your comparison of actual with the standard for trim, overweight, broke, and defective paper would allow you to trace and remedy the causes of excesses.

In an ocean clam processing company we studied the same problem, namely, yield, and discovered many interesting losses: since the shuckers were on piece rate they threw broken clams into the shell barrel because these took longer to shuck, they often stuffed shells or clams into the drain holes of the pail or banged in its bottom as in a wine bottle,

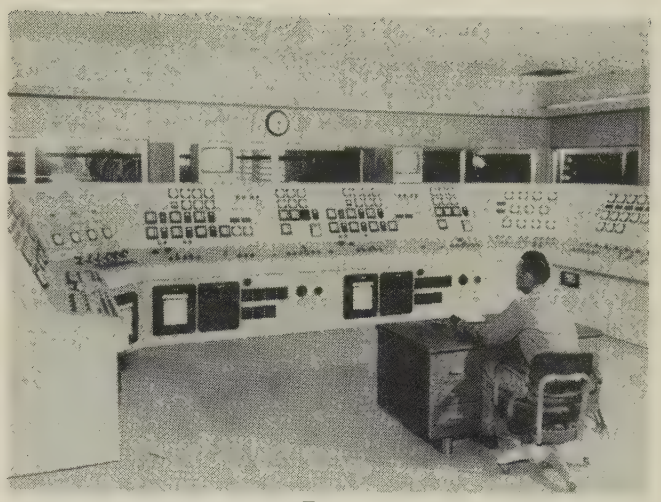


Fig. 2

so as to make the pail fill up sooner. By having them shuck a bushel of clams at a time instead of from a bulk pile and by having them put both clams and juice into a pail that would accept only one bushel, we were able to increase the yield from under 11 to 12 lb. or over 11%. I am not trying to say that shellfish processing is the same as papermaking, but I am saying that detailed analysis, if only on a one-shot basis, produces measurements which justify the original engineering and the resultant changes in equipment. Also, it is interesting to note how greater control was obtained by breaking the production flow into smaller elements, that is, from a table full of clams to bushels. I am saying that you may well find that setting up profit or cost centers within your plant, better still on each run, will produce increased profits and quality. Science has grown vaster as the scientist studied nature in greater detail, first fire, water, air, and earth, then the 90-odd elements, then the molecules and atoms, and now the electrons. Similar advances are made in business as the executive studies his operations in greater detail.

There is, I believe, a direct comparison possible between the finishing operations which require most of the labor in a paper plant and the mentioned instrument company and Northrup Aircraft. Here performance reporting would deliver economies and speed delivery of desired items. Finishing room costs are also helpful in operations research analysis to determine the best inventory quantity of finished goods, as was suggested earlier. In the operations research formula, rate of sale, the costs of stocking uncut and cut paper and the cost of being out of stock are considered so that the finishing room produces goods in such a way as to achieve the desired level of profits and customer service. On the most elementary level, there should be no running out of the most popular size. On the more sophisticated level, studies might indicate the desirability, say, of stocking blanks and cutting sizes only on order. For instance, one grinding wheel company is thinking of stocking a certain type of wheel in one size and drilling out material or adding a hub to give the correct size hole for each order.

Again it is fortunate in that a performance reporting system, as suggested earlier can be carried out manually in order to estimate accurately the possible benefits of collecting the data mechanically. Frequently the largest improvements or best return on investment are obtained with manual or semi-mechanical systems. If it has not already been accomplished, the simpler improvement is likely to bring the greatest return on investment. On the other hand, some companies may wish to take several steps at a time to achieve largest savings.

In summary, just as there is a formula for each type of paper you are making, there is a matching mix of costs. The immediate collection and correlation of these costs will often allow control of costs even before they become excessive. It will allow higher quality and faster delivery.

Certainly if the supposedly antiquated post office can use the advanced techniques of operations research and a control center, then private, efficient industry should be able to go one better even if the only way it can foot the bill is through a cooperative effort spearheaded by a group such as TAPPI. Or on projects such as developing an integrated data handling system for the paper industry we can obtain funds for sponsoring the necessary research when a company or a group of companies is willing to co-sponsor or place an order for the first system.

An article, "Next—Computers Run Plants," states: "Computer control of processes could not only permit plants of contemporary design to operate at higher efficiencies but also make it possible to design chemical process plants that are vastly more complex, to operate at tolerances of temperature and pressure that are unheard of today. In existing chemical plants, the most alert crew of operators can run the plant at 85 to 90% efficiency. Spokesmen of Daystrom and Ramo-Wooldridge say equipment now being developed is capable of running plants at close to 100% of maximum output" (*5*). I suggest the same may be true in papermaking plants.

It remains for some pioneering company or association such as TAPPI to take this bold step toward the automatic factory.

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Ohio

The following paper was presented at the meeting of the Ohio Section which was held Sept. 15, 1959.

Direct Gas Drying of Inks and Adhesives

Carl P. Mann

Modern industry finds it necessary to constantly improve the quality of its product and its production methods, and these production methods must attain the greatest production possible from every square foot of manufacturing floor area. In addition, man-hours available must be used in the most economical way.

In applying this broad principle to heat processing operations, it means that heat must be transferred from the heat source to the work in process as rapidly as possible.

In general, heat may be transferred from a heat source to the work by employing a low temperature thermal head for a long time period, or by a high temperature thermal head for a short time period.

There are, of course, some practical limitations in the actual application of this general principle. Some heat processes involve a chemical change, the nature of which is such that the change requires a definite temperature for a definite time period. Sometimes the nature of the material is such that it can tolerate only a relatively low temperature. Frequently, the heat process involves moisture removal from material having appreciable depth, requiring moisture migration from the inner structure to the surface by capillary action. If heat is applied to the surface too rapidly, this capillary action is interrupted, and the drying rate is retarded. A somewhat similar limitation may be encountered in heat curing material of substantial thickness which must be heated uniformly throughout its thickness. If the thermal head applied is too great, the surface may attain a destructive temperature before the center of the material has reached the necessary curing temperature. Again, the removal of moisture or volatiles from a relatively thin material may become so rapid by employing a high thermal head, that the surface luster is adversely affected due to microscopic craters caused by the rapidity of the phase change from a liquid to a vapor.

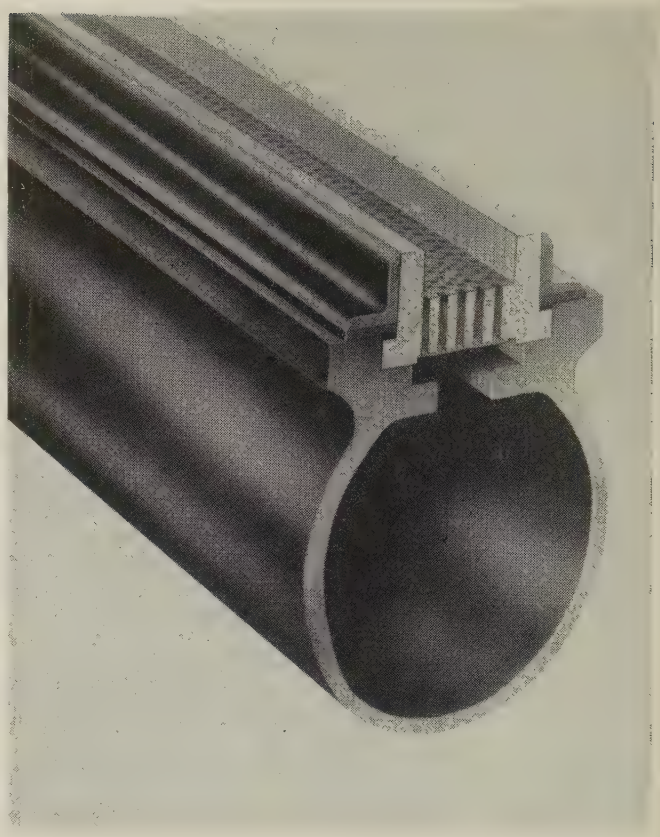

Fig. 1. Sectional view of refractory ribbon burner

Direct gas drying employs very high thermal heads, and the necessarily high temperatures required for these heads are obtained either by direct contact with the gas flame or by converting the heat of the gas flame to radiant heat and applying this radiant heat to the work, or a combination of both. There are a number of different types of burners which are used for direct flame contact with the work in process, depending on the operation to be performed and the character of the work piece. For low intensity applications where small turndown ratio is required, the ordinary drilled pipe ribbon burner may be used. Where high intensity is required for high speed production, or the control covers a considerable range, requiring a large turndown ratio, the design of the ribbon burner becomes more elaborate and refined. Figure 1 shows in a sectional view the construction details of a ribbon burner that is engineered for high production work and is extremely versatile, making it adaptable to a great variety of uses. It consists of a cast iron manifold into which are inserted precision refractory sections containing the burner ports. The deep ceramic ports provide an insulating barrier between the flame and the stoichiometric air-gas mixture in the manifold which makes it possible to develop a very high capacity flame, and also a very short and low flame without overheating the incoming fuel; a frequent cause of backfire in a burner. The flame side of the refractory ports is designed to form a refractory tunnel which pilots the flame and gives the burner extraordinary flame retention qualities at

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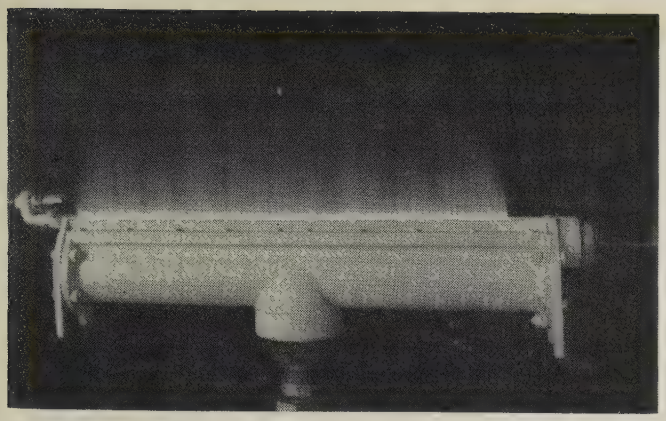

Fig. 2. Ribbon burner with flame stop in operation

very high burning rate without flame blow-off. Immediately beneath the refractory, between the bottom of the ports and the burner manifold, is a slot into which a flat bar or flame stop may be inserted to provide a means of adjusting the flame longitudinal dimension accurately to varying widths of work. In applying heat to paper webs, it is usually found that a great variety of web widths must be handled. This flame adjusting device permits a single burner to accommodate a great many web widths. Figure 2 is a photograph showing the flame of a ribbon burner which has been shortened on one end for a distance of about one inch by the insertion of a flame stop.

In order for direct flame applications to be most effective at high web speeds, the flame must have stiffness so that it can break up the thin layer or stratum of cold air which clings to the surface of the web.

The burner just described does develop a very stiff flame due to its high flame retention qualities.

One of the great advantages of the radiant burner is its ability to transfer heat to the traveling web without interference from the cold air stratum because air is transparent to radiant heat rays.

The heat of a gas flame is converted to radiant heat by causing the flame to burn along the surface of insulating refractory material. Figure 3 is a sectional view of a radiant burner illustrating how this is accomplished. The air-gas fuel mixture is fed through the threaded connection at the bottom and flows through the orifices in the threaded burner tip which is located in the center of the bottom of a ceramic

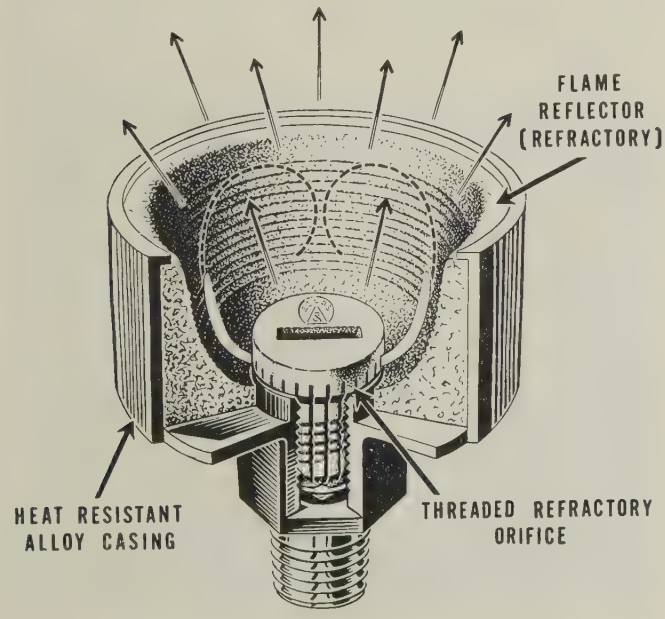

Fig. 3. Radiant-type air-gas burner

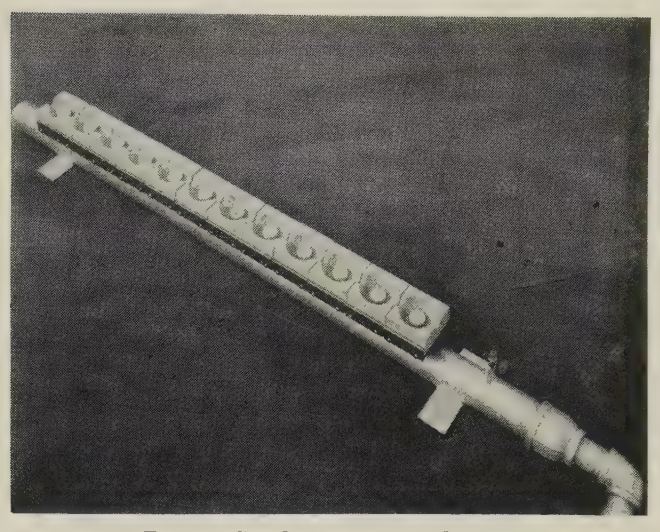

Fig. 4. Single row radiant burner

cup-shaped reflector. The flame of the burner is constrained to wipe the inside surface of this reflector, thus heating it, and the shape of the reflector directs the radiant rays to the work. This radiant heat not only penetrates the air between the burner and the work, but this heat travels at the speed of light. Furthermore, the rate of heat transfer is proportional to the fourth power difference in temperature between the heated surface and the work, so it is obvious that high thermal heads can be very effective.

For applying radiant burners to webs of paper or metal, a multiplicity of these burner units are mounted in rows to cover the full web width. Figure 4 is a photograph of one row of burners for a 36-in. web.

In the metal industries, the use of very high thermal heads has long been accepted practice, and in recent years great improvements have been made in the techniques of applying higher and higher thermal heads. In the heat processing of combustible materials, however, the application of higher thermal heads has been a relatively recent development. This presentation will describe direct gas drying both on metal and on combustible materials.

In the manufacture of steel strip, it is frequently desired to print identifying characters on the strip, and in order that these characters shall not be smeared in the subsequent winding into a roll, this printing must be dried. Another very similar application is to be found where metal strip is being plated. In this latter instance, the plated strip is passed

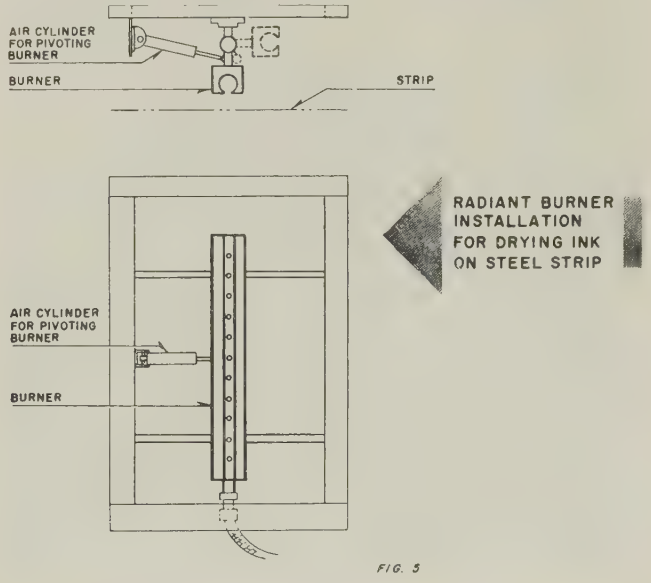

Fig. 5

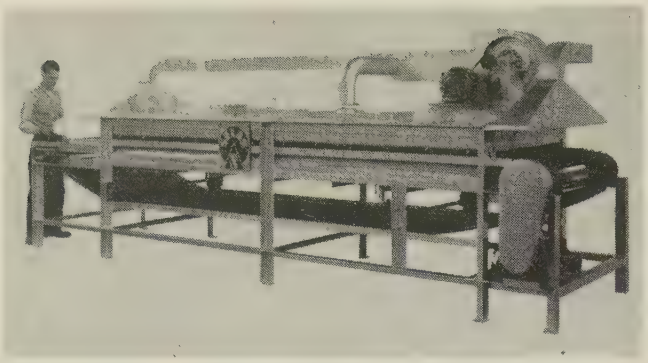

Fig. 6. Radiant burner drier for coated metal sheets

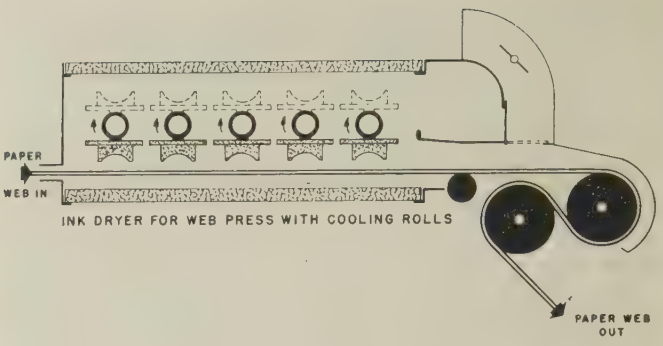

Fig. 8

through an automatic inspection station which can detect any spot where the plating may be faulty. Whenever faulty plating appears, the inspection device prints a mark on the strip, and this mark must be dried before it reaches the rewind.

The drying of the printing in both of the above applications is an excellent opportunity for the use of direct gas drying. The metal is noncombustible, and very high thermal heads dry the ink almost instantaneously. At a speed of 1200 f.p.m., radiant heat applied over a 3 ft. distance of strip travel dries the ink. This means an exposure of 15/100 a second to radiant heat does the job. Figure 5 is a line drawing showing how this installation was made. The 3 ft. long radiant burner was located in close proximity to the strip with the long dimension in the direction of strip travel. In order to avoid overheating the metal in case of stopping of the strip, the burner is automatically rotated 90° by a piston actuated mechanism, and the flow of air-gas fuel to the burner is reduced to a pilot flame. When the strip starts again, the burner is automatically returned to its operating position and fuel is fed at full capacity.

When ink is applied over the full width of the strip, then the burners are mounted across the width of the strip and a multiplicity of burner rows are applied, one after the other; the number depending on strip speed and the character of the ink or coating that is applied. Figure 6 is a photograph showing a conveyorized oven equipped with rows of radiant burners used to dry a noncombustible heat sensitive coating applied to flat pieces of metal. The conveyor consists of crossbars located close together and carried on each end on a roller chain. These crossbars have sharp points protruding upward on which the metal pieces are placed, the purpose of the points being to prevent conduction of heat away from the work pieces by the conveyor. In this instance, the exposure time to the heat is in the order of five seconds.

In the manufacture of certain kinds of insulated wire, the wire is coded by applying a continuous line of colored ink on the surface of the insulation. By using a variety of different colors, the electrician is enabled to trace his wiring. In this case, the ink is sufficiently heat sensitive to respond to a very high thermal head for a very short time. Figure 7 shows a laboratory demonstration of a burner used for this application. In this instance, both radiant heat and the heat of the products of combustion are utilized to make a most efficient use of the burner. The burner is so constructed that the wire may be inserted directly into a small radiant chamber which completely envelopes the wire and which confines the hot products of combustion. This is accomplished by providing a narrow slot through which the wire is admitted. If the wire is stopped, the wire is automatically and instantly withdrawn from the radiant chamber through the same slot by a special mechanism.

Drying ink on paper is a much more sensitive process than drying ink on metal and requires an extremely precise balance between the temperature applied and the time of exposure to the heat. In direct gas drying, the time is a matter of fractions of a second. Paper is scorched at a temperature in the order of 300°F., depending on the period of time it re-

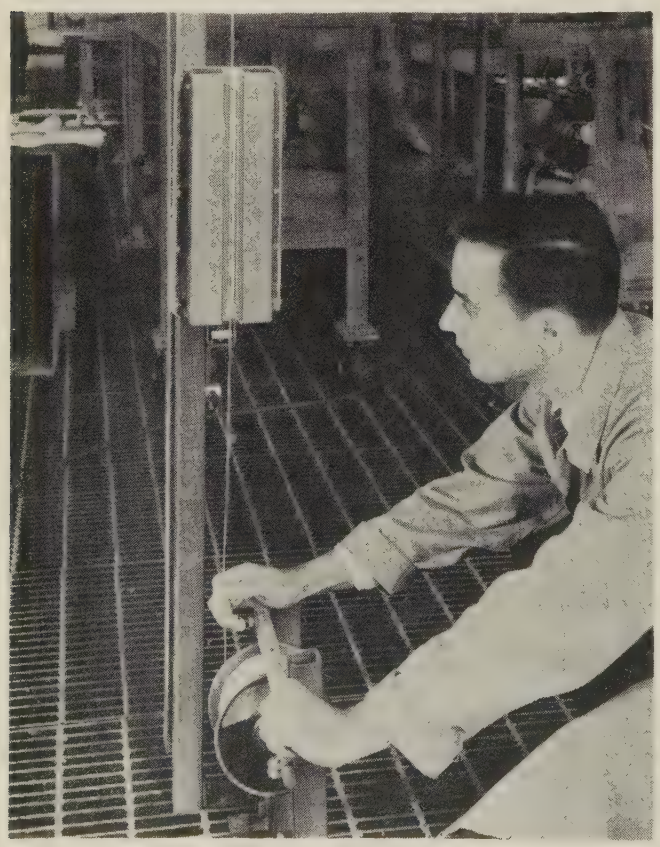

Fig. 7. Radiant burner for drying ink on insulated wire

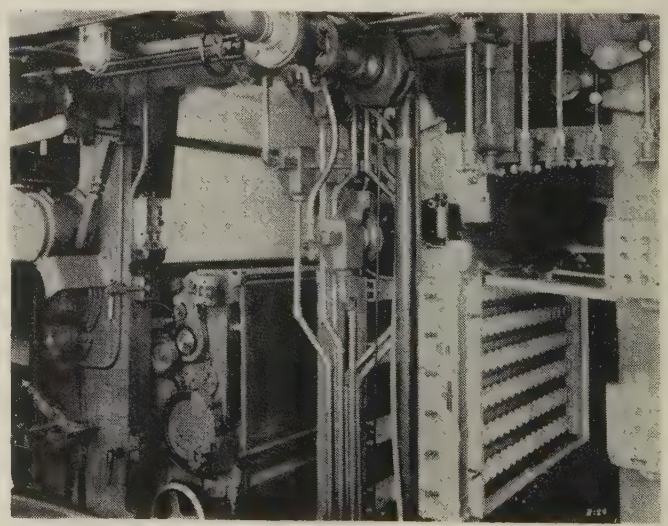

Fig. 9. Radiant burner drier, second impression, 2-color press

Fig. 10. Ribbon burner drier for bag printing press

mains at that temperature, and some of the desirable characteristics of paper are lost at temperatures only slightly below the scorching point. In order that a successful ink drying process be attained, it is necessary that the ink dry rapidly at a temperature below that which will adversely affect the paper, and yet remain stable indefinitely at ordinary room temperatures. In the printing industry, ink manufacturers have solved this problem most satisfactorily so that today web speeds have reached over 1500 f.p.m., and this speed limitation is imposed by printing mechanisms rather than by ink formulations.

On printing presses, direct gas drying is effected by either radiant heat or by direct flame contact, and the choice of which to use is largely a question of details of controls, press design, and economics.

In applying direct gas drying to paper webs, the matter of speed and precision in control is many times more important than the similar process on metal. A printing press can decelerate from the full press operating speed of 1200 to 1500 f.p.m. to a dead stop in a few seconds, which means that the heat in the temperature range of 1800 to 2000°F., which has been used to dry the ink at a temperature within 10 to 15°

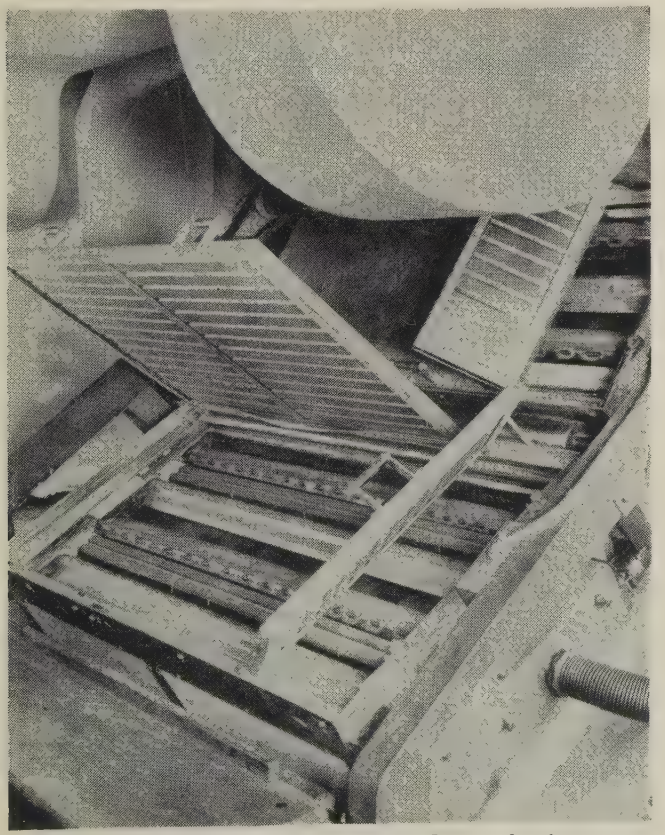

Fig. 11. Ribbon burner drier, two-color perfecting press, second impression

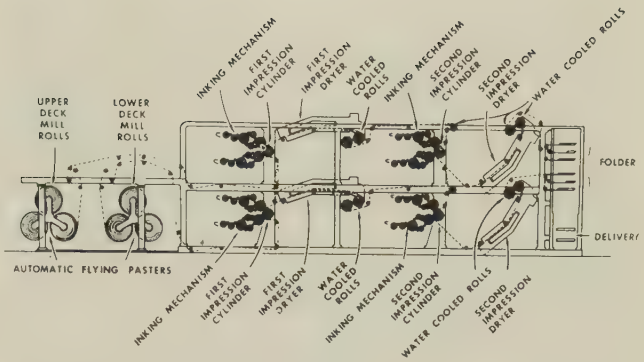

Fig. 12. Ribbon burner driers on two web two-color, also single web four-color perfecting web press

of the spoiling temperature of paper, must be immediately reduced to 250° or less. In starting up a press, the reverse holds true, though normally a press is not brought up to full speed quite so rapidly as the pressman must maintain their printing register.

A number of different devices have been developed and used for preventing web scorching due to quick stops. Where radiant burners are used, a variation of the burner rotation mechanism described above on steel strip has been widely used. Figure 8 is a cut showing a cross-sectional view through a five-manifold radiant ink drier. The solid lines show the burner and damper position while the web is in motion; while the dotted lines show their position with the web at rest. When the press is in operation, the burners are operated at full capacity and their radiant heat is directed to the web, and the products of combustion travel toward the water cooled rolls and upwardly out through the exhaust hood. The drier control is interconnected with the press control so that immediately the stop button of the press is operated, the burners rotate 180° away from the web, the burner firing rate is reduced to a pilot flame, and the products of combustion are exhausted from the top of the drier through the exhaust hood. Figure 9 is a photograph of one of these driers applied to a web traveling in a vertical position. The top of the drier is raised to show the burner rows.

Where flame contact ribbon burners are used for ink drying on paper, the rows of burners are placed across the web so that the stiff flame of the burner contacts the paper. When the web is stopped, the flame is turned completely off and cold air is blown against the web between the burners to keep the paper cool. Figure 10 is a photograph of a ribbon burner drier for a narrow web, and Fig. 11 shows a ribbon burner drier with the cover raised to expose the burners to view.

A very common form of press used for printing magazines prints both sides of two webs and combines the finished printing in the folder. Figure 12 is a cut showing the side view of

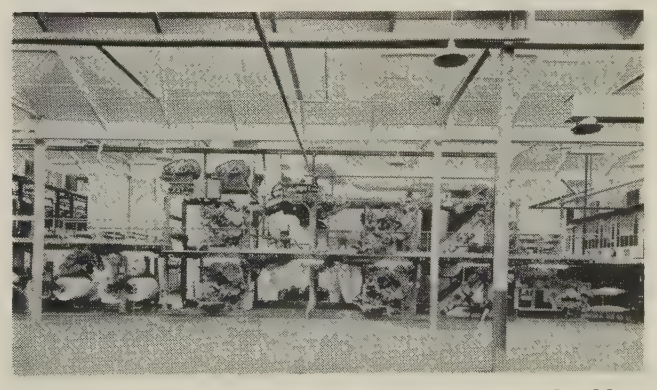

Fig. 13. Two web, two-color perfecting press with ribbon burner driers

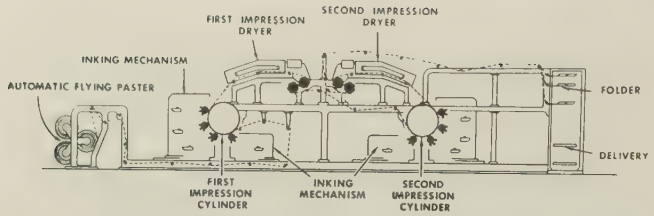

Fig. 14. Ribbon burner driers on four-color perfecting web press

such a press equipped with ribbon burners. It is to be noted that there is one drier after each printing station, and in this case, the top side of each web is first printed and dried, and then the bottom side of each web is printed and dried. At each of these stations, two colors are printed on the paper. This same press can be used to print a single web with four colors on each side by running the single web from the mill roll through the bottom deck printing unit, then to the top deck printing unit, then to the first top deck drier and then continue to the top deck second printing unit, thence to the

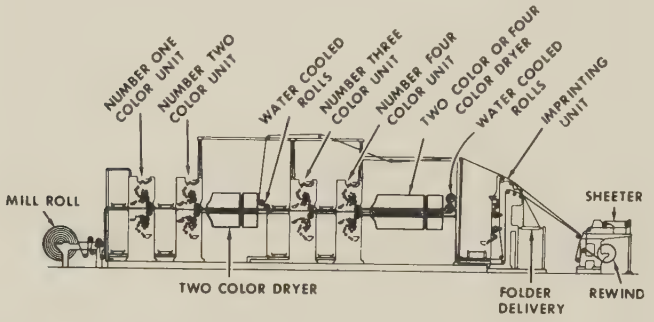

Fig. 15. Ribbon burner driers on two-color; two web; or four-color single web offset perfecting web press with imprinting unit and folder, or sheet delivery, or rewind

bottom deck printing unit, through the bottom deck drier and then to the folder. Figure 13 is an unusual photograph of an actual installation of a double deck two-color press.

A very common design of a single web four-color press is illustrated in Fig. 14 which shows a ribbon burner drier after each four-color printing station; one for each side of the web.

All of the printing presses described so far have been typographic presses, where the ink can be applied on only one side of the paper at each unit. When printing by the offset print-

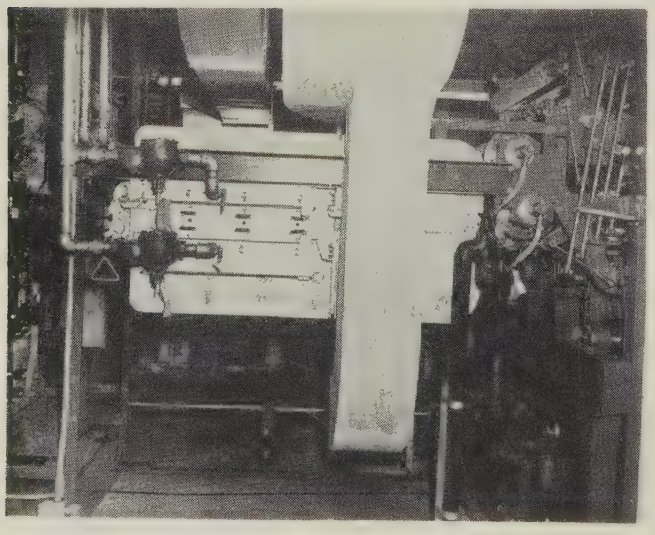

Fig. 16. Ribbon burner driers, four-color offset press

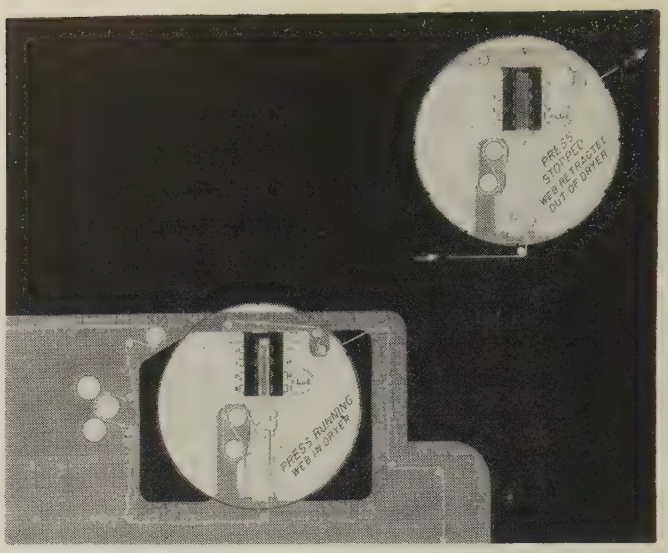

Fig. 17. Cut showing operating principle of retractable web drier

ing process, it is possible to print both sides of the paper at once at each station. Figure 15 is a cut showing a typical offset press which prints two webs two colors each side, or a single web four colors each side. It is to be noted that in this instance, a single ribbon burner drier can be used for drying both sides of the web at once. These ribbon burner driers have ribbon burners placed opposite each other on both sides of the web so that only half the number of drying units are required to do the same drying work on an offset press as on a typographic press. Figure 16 is a photograph of a double sided drier installed on an offset press, printing four colors on both sides of the web.

In all of the ink drying applications cited above, the problems of applying the high intensity heat while running and of removing this heat while stopped has been solved by moving the heat. Another unique and very successful device which

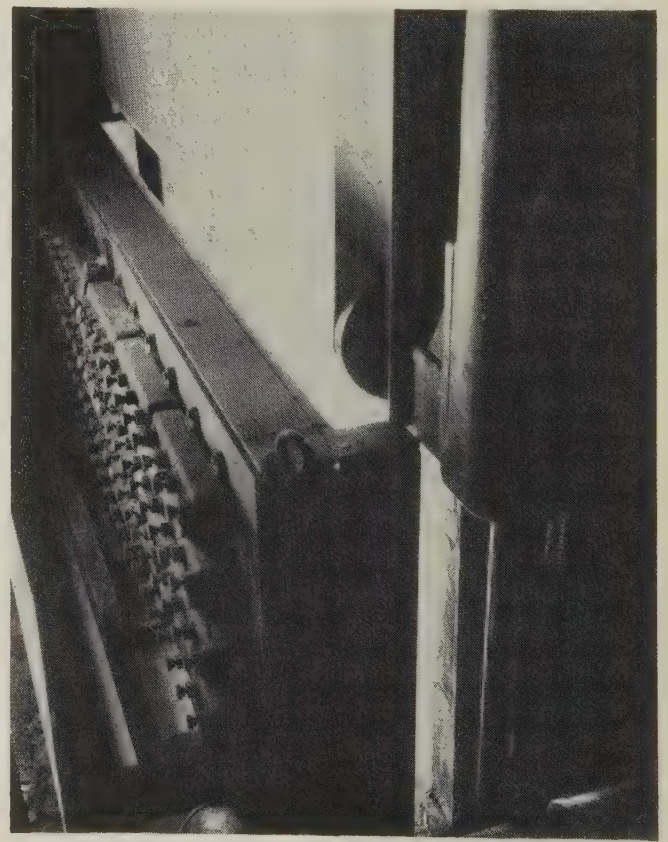

Fig. 18. Retractable web drier in operation

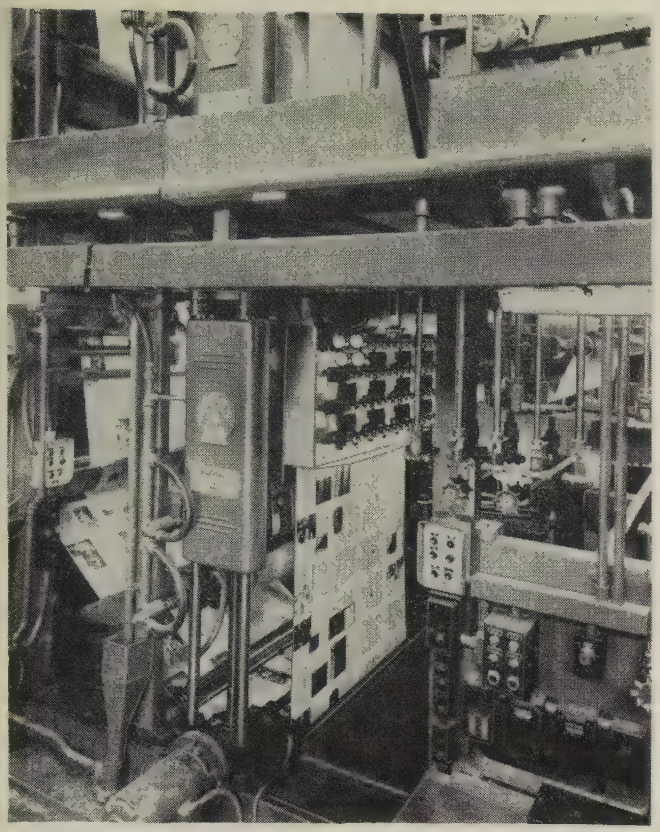

Fig. 19. Retractable web, two web, two-color perfecting press, second impression

has been developed to solve this problem is based on moving the web instead of the heat. Figure 17 is a diagrammatic cut showing the operating principle of this device. The lower cut of the figure shows the web leaving the printing unit at the left, passing under the drier (printed side of the paper down), then up into a gas fired radiant chamber where the heat of the radiant burners is directed on the printed side of the web. This web is supported in the radiant chamber on two rolls which may be moved vertically, and in the lower cut, the rolls are shown in their upward position as they are when the press is running. When the press is stopped, these two rolls are automatically moved downward, so that the web is instantly removed from the heat. A study of the diagram shows that this movement involves no change in the length of the web lead. Figure 18 is a photograph showing a web withdrawn from the radiant chamber. In this case, the arrangement of the chamber and web is the reverse of that shown in the cut, as the chamber is at the bottom. Figure 19 is a photograph showing one of these driers applied to the second printing unit of a double deck two-color press. Figure 20 is a photograph of a single web four-color press using two retractable web driers. This arrangement results in the most compact assembly of printing unit and ink drier yet devised.

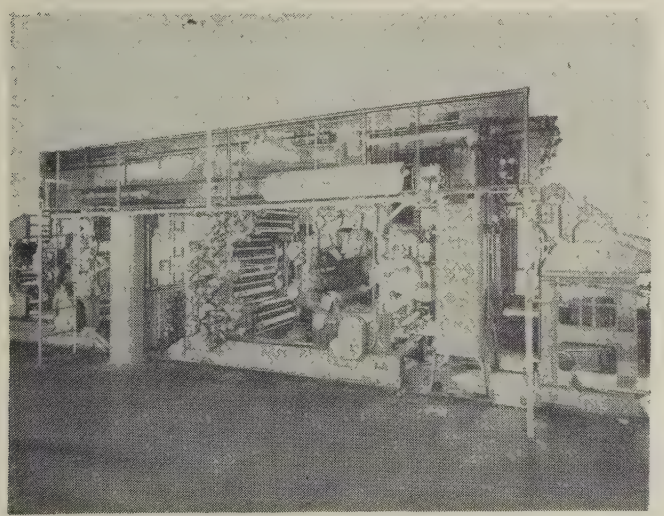

Fig. 20. Single web, four-color perfecting press with retractable web driers

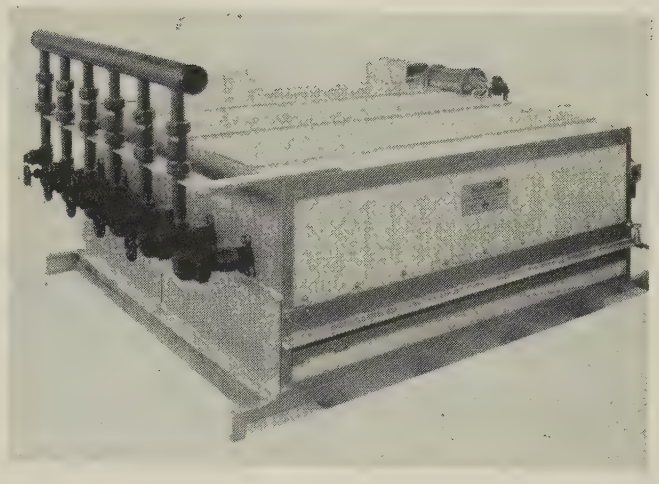

Fig. 21. Radiant burner drier for drying gummed paper

Radiant heat has been applied in numerous instances for drying the adhesive applied to paper.

In the book binding industry one operation requires that glue be applied to the backs of books after they have been sewed and before the crash reinforcement has been applied. The glue used in this operation requires from four to eight hours to air-dry, depending on the atmospheric humidity. Because of this, large floor space is required to store the books while drying, and there is much manual rehandling of the books.

By a properly designed system, the glued backs of these books may be exposed to radiant heat while on a conveyor, and the heat will dry the glue in four minutes. This heat application makes this operation independent of weather conditions, saves great floor area and expensive unnecessary rehandling.

In the manufacture of gummed paper, the direct application of radiant heat is being used to accelerate the drying of the adhesive. This is accomplished by passing the gummed side of the paper under radiant heat immediately after the gumming operation, thereby adding the sensible and latent heat to the adhesive to bring the moisture in the glue to the evaporating point, and then finish the drying in a convection drying operation. The radiant drier used for this operation is shown in Figure 21. The burner rows with their turning

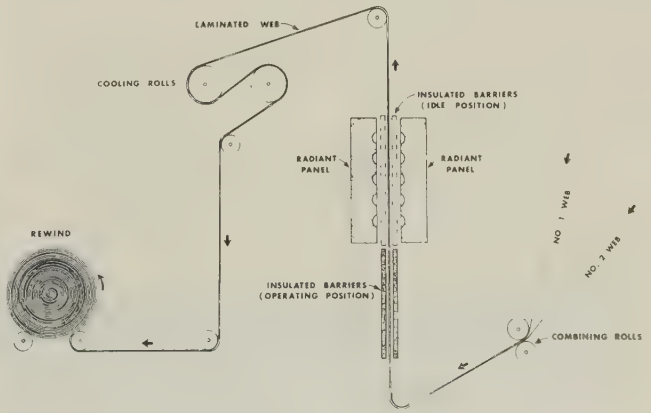

Fig. 22. Drying moistureproof laminated paper between radiant panels

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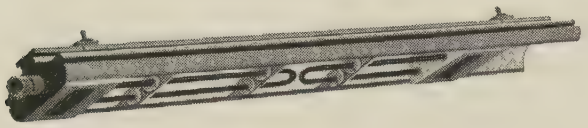
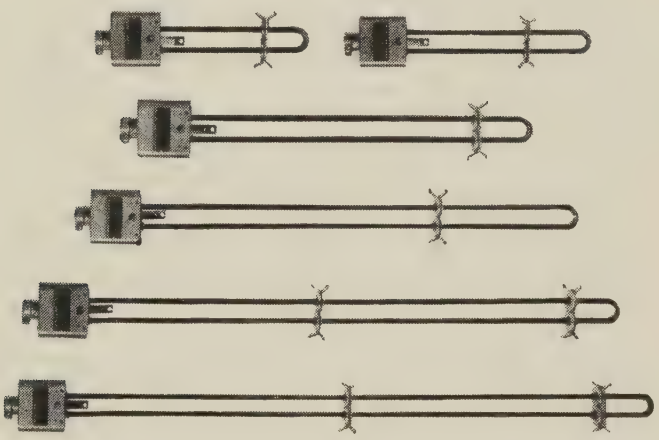


This Chromalox URAD heater lets you match your heat source to your work area. In one basic housing you can install up to 27 different heated lengths; each can be varied with the area of the work.



You can do-it-yourself too. Chromalox Far-Infrared elements are designed with a sliding fit that lets you interchange elements anywhere along the housing length. No more wasted heat when you go from one work size to another. This versatility means real dollars and cents saving.

Chromalox Electric Far-Infrared radiation can be simply and precisely controlled over largest work areas, and is absorbed uniformly by practically all colors—even optically transparent materials.

FREE—Get more information about Chromalox Electric Far-Infrared Heat. Ask your Chromalox Representative, or write today for your copy of new Catalog G-62.

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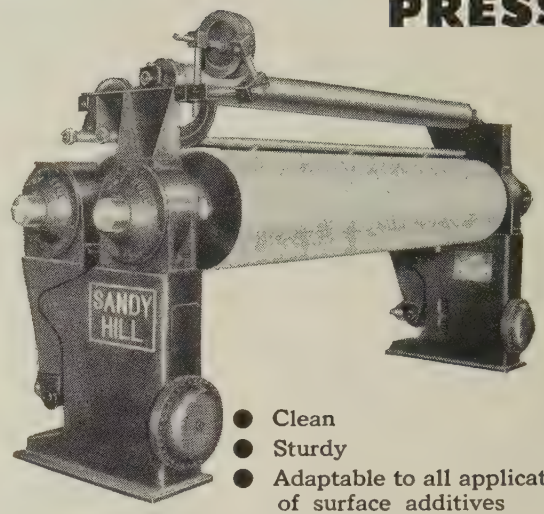

- Clean
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devices are quite similar to the radiant driers described first above for drying ink on printing presses.

In the manufacture of one design of paper milk bottles, radiant heat is used to heat seal and final seam of the bottle. One interesting aspect of this operation is that in this instance, the heat is applied to the side of the paper opposite to the adhesive so that the radiant heat must penetrate through the thickness of the paper to dry the adhesive.

In the manufacture of aluminum foil, the adhesive used to laminate the paper to the aluminum web is dried by passing the laminated web under a ribbon burner, after which the web is rewound.

One manufacturer of moistureproof paper used for cement bags and similar moistureproof papers uses direct exposure to radiant heat to laminate two webs of paper together as shown in Figure 22. The two webs of paper, each having a coating of a moistureproof adhesive, are brought together at the combining rolls with the adhesive treated sides toward each other. The combined web is then passed between two radiant panels which provide the heat necessary to seal the adhesive after which the laminated web is cooled and then rewound. In this instance when the web is stopped, a heat barrier is inserted between the web and the radiant panel, and the air-gas fuel to the panels is turned off so that the heat barrier protects the paper from the residual heat of the panels.

This presentation has been made to acquaint you with a diversity of direct gas applications which have been developed to date. While some of these problems have been solved rather easily, others have been solved only by extensive research and collaboration between manufacturers of paper, inks, presses, and heating engineers. New applications are constantly arising which means that there are new opportunities for forward looking men in the paper, chemical, machinery, and heating industries to pool their knowledge and experience so that industry may continue to ever increase its productivity and effect greater economies in manufacturing methods.

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